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Oil and Gas Lamps

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AMONG the important scientific developments which ripened into active agents during the past one hundred years for the daily benefit of man, artificial illumination necessarily takes its place as one of the chief factors in our modern civilization. Not only does it assist in prolonging the hours of both work and pleasure, but it is one of the chief agents in diminishing crime in our crowded cities. It is a well-known fact that where streets and places of public resort are well illuminated, crime becomes a vanishing quantity.

In the forward march of civilization, lamps have followed very much the same course as have methods of transportation. At first progress was very slow; the then existing means of transportation were in vogue for centuries. If man traveled at all, it was on foot or, perchance, on the back of a camel or donkey. Later came the sailboat, the wagon, the steam train and boat, and finally the automobile, the motorboat, and the airplane. All these means of transportation are still in existence and each has its peculiar use. This is also true of lighting. Before the Christian era, torches and fagots were practically the only illuminants. Gradually, various types of animal oils, such as whale oil, lard oil and the tallow dip, and vegetable oils such as olive oil, came to be used. The candle made its appearance.

In the case of transportation, methods are developing in which we are more and more dependent on the help of other people. Likewise, in lighting we have changed from the torch and candle, which were self-contained and independent, to the modern systems where the whole community may be in darkness if something goes wrong at the power plant. As in the means of transportation the most rapid changes were made during the last century, so in the realm of lighting the changes from one system to another occurred in ever quicker succession during the same period. In both cases, the curve of progress becomes much steeper as we approach the present, and shows no tendency to flatten out. We may be able to detect part of the reason for these accelerated changes in the things themselves. When man was able to move about more rapidly, he had more time to think of changes; he really lived more. In lighting, as newer types were developed, man extended the length of his working day and hence lived more for that reason. In transportation, he went from land to water to air; in lighting, from incandescence to luminescence to fluorescence.

Coming now specifically to the part oil and gas have played in our scheme of lighting, we note that in both cases the light is furnished almost entirely by the incandescence of carbon particles. The sudden and complete combustion of carbon would not result in light, and carbon at a low temperature would not furnish light efficiently.

The numerous sources of nonelectric artificial illuminants now available for indoor, as well as outdoor, illumination vary so in quality and source that it is impossible to describe them

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adequately in a small space. The difference between the humble tallow candle and the intense light of the incandescent mantle is wide.

Illuminating Gas

The heat obtained from natural gas is about 1200 B.t.u./ft³ and, therefore, natural gas lends itself readily to use with incandescent gas mantles. It issues from the earth with a pressure of 300 to 400 lb/in.². Its explosive range is from 5 to 12 percent. It was first used as an illuminant in this country in 1821.

Artificial gas has been used for lighting since about 1782. There are two principal kinds—coal gas and carbureted-water gas. Coal gas is made by the destructive distillation of coal. Water gas is made by passing steam over red-hot coal. The steam is decomposed and the oxygen combines with the carbon to form carbon monoxide. It is then carbureted by adding oil. Of the two, water gas has the higher illuminating power. Its explosive range is approximately from 7 to 20 percent.

Kerosene

Kerosene is a mixture of several hydrocarbons. When ignited in the presence of the right amount of oxygen, it forms carbon dioxide and water. If there is insufficient oxygen, the carbon will get red hot and cool off again without burning; then the lamp smokes. If there is too much oxygen, the carbon burns to carbon dioxide without producing light.

The illuminating power of kerosene, which is usually expressed in candlepower hours per gallon, varies with the height of the flame. When the flame is low, the illuminating power is low, because then some oil escapes unburned; when the flame exceeds a certain optimum height, the illuminating power is again low, because then the carbon gets only red hot. Those kerosenes that have a high illuminating power are found also to be high in density, index of refraction, viscosity, surface tension, flash point and burn point.

Figure 1 shows a bird's-eye view of the distribution of light from a kerosene flat flame. The distribution is not described by the cosine law; the flame is very attenuated and the candlepower remains almost constant in all directions

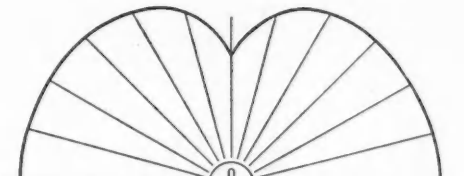

Fig. 1. Distribution of light from a kerosene flat flame.

out from the equator. There is a slight decrease in candlepower when the flame is viewed edge on; in that direction, the flame corresponds to a mercury or sodium arc, where the candlepower varies but the brightness remains constant. In every other direction, the candlepower is constant but the brightness varies. The low brightness of the kerosene oil flame is in its favor. It varies with the height of the flame and is about 6 candles/in.² when the flame is at its optimum adjustment.

Kerosene was first used as an illuminant in 1853 and by 1860 its cost had risen to $2 per gal. In many rural districts and isolated dwellings, the kerosene lamp, with or without mantles, is practically the only illuminant used today. Only about one-fifth of the farms in the United States are electrified. It is little wonder that kerosene has held on so long as an illuminant; for, as regards cost of installation or general adaptability, it provides the most economical system of illumination available. It is a self-contained, portable and very reliable source of light. The consumer who depends on kerosene lighting is not at the mercy of a transmission company for continuous service and, because of its portability, he has available a means for lighting any corner of a building, yard or farm.

Acetylene

Lighting by acetylene dates back to the time when calcium carbide was first made. That was before 1880. Acetylene (C_2H_2) is formed by the combination of water and calcium carbide. It is

an endothermic substance; that is, in its production a certain quantity of heat is absorbed and transformed. For this reason, the gas is unstable under certain conditions of temperature and pressure. It consists of an equal number of carbon and hydrogen atoms, and the proportion of carbon atoms is much greater than that in any other hydrocarbon used as an illuminant. Thus burners with very small openings must be designed for acetylene so as to allow ready access of oxygen from the air for the complete combustion of carbon. Even at that, the carbon in an ordinary acetylene flame gets only white hot, and this accounts for the color peculiar to this flame. The flame is very hot because of the large amount of oxygen used, and thus it lends itself well to the use of a mantle. Its explosive range is from 3 to 50 percent.

At a pressure of 10A, acetone can absorb as much as 240 times its own volume of acetylene. This is the fuel for the Prestolite lamp, formerly used on automobiles. In mountain regions where electricity is not available, acetylene flares have been found useful.

Other Hydrocarbon Sources

There still remain to be mentioned three lamps whose source of energy is petroleum—the gasoline lamp, the Pintsch gas lamp, and the Blau gas lamp.

Gasoline is used in portable lamps and lanterns, and in stationary lighting systems installed in large buildings. A mantle is invariably required. The light is intense because of the large heat of combustion of gasoline, and the cost of the open flame is small. Its explosive range is from 2 to 5 percent.

For a long time after 1880, railroad coaches were lighted by a gas made from petroleum by the process of destructive distillation. It is known as Pintsch gas, after Julius Pintsch, who developed the process. It has to be stored in tanks under pressure but, unlike most other gases, does not lose in illuminating power when released from pressure. It lends itself readily to use on trains because it burns well with mantles and does not explode easily. The latter property is especially desirable on trains, where wrecks may occur. It is difficult to light when escaping under high pressure. Its explosive range is from 4 to 10 percent.

Another product of petroleum known as Blau gas can be used as an illuminant when a mantle is employed. It is more highly refined than Pintsch gas, and is not poisonous. Its explosive range is from 4 to 8 percent.

Danger

There is some danger, of course, in using any kind of lighting system. Each system has its own advocates among those who have successfully operated it, and has its unfavorable critics among those who have not used it at all or who have used it carelessly. The reports of fire marshals concerning lighting systems seem to differ so widely that very few, if any, definite conclusions can be derived from them. It seems certain, however, that almost all the danger arising from any system—oil, gas, or electric—is due either to ignorance or to carelessness on the part of the consumer.

The Welsbach Mantle

When the Welsbach mantle was developed (1886), there resulted an increase of approximately 300 percent in the light output of all nonelectric illuminants. The color and candlepower of the mantle lamp depend on the constitution of the oxides impregnated in the mantle. The maximum candlepower seems to be obtained when the salts are thoria, 99 percent, and ceria, 1 percent.

In using mantles we are still depending on incandescence; but now it is the impregnated mantle that is incandescent rather than the carbon particles of the fuel. For this reason, a high temperature is necessary for good results. Since the color of the light depends upon the oxides used and can be made nearly white if desired, the advent of the mantle proved quite a boom to the gas industry, for at that time the light from an electric incandescent lamp was far from being white.

In recent years, the Humphrey's Super Candlepower gas lamp has made a remarkable showing of the marvelous qualities of light obtainable from gas which no other form of artificial lighting can begin to approach. This lamp takes gas at

ordinary main pressure and, by means of an electrically operated supercharger, delivers to the burner a premixture for intense combustion. Mantles produced under a newly patented process become highly incandescent under this high temperature activation. Provision is made for ignition and extinction of the flame under reduced mixture, thus avoiding the explosive effect otherwise attendant.

Flame Standards

In their day, oil and gas lamps have also furnished their share of standards by which to measure light output. As a working standard, candles made of sperm oil have in their favor the weight of long usage and a light of correct color value for comparison with most nonelectric illuminants, but they are not constant and many factors must be specified. The Carcel and the Hefner lamps are little used in this country. With proper precautions, either the Elliott kerosene lamp or the pentane lamp can be used as a standard for gas photometry. When testing ordinary nonelectric illuminants, it is desirable to use one of the foregoing standards, both because of their color value and because atmospheric conditions will affect standard and unknown alike.

In order that a Welsbach mantle lamp may serve at all as a standard, it seems necessary that it be aged for at least 200 hr. Acetylene in a burner giving a long, thin, cylindrical flame has also been used in a design for a standard light source. It is insensitive to air currents and has a uniform intensity over a considerable length. The results show that such a burner is sufficiently accurate and reliable for all ordinary purposes. The only apparatus necessary to control the intensity is a simple water manometer.

The Jones jet photometer, using water gas, and other photometers of a similar character give merely an indication of the candlepower of a gas.

Brightness

Experiments indicate that for protection of the eye the brightness of a small source should not exceed 3 candles/in.^{2}, or 1356 ft-lamberts. For large sources the brightness should be less, because a larger area of the retina is affected.

Table I. *Brightness of sources.*

Source	Brightness (cp/in.^{2})	Source	Brightness (cp/in.^{2})
Candle	3	Carbon incandescent	580
Kerosene, bare flame	6	Mazda vacuum lamp	1000
Acetylene, bare flame	20	Mazda gas-filled lamp	4000 or more
Illuminating gas, bare flame	10	Mercury arc (glass)	15
Welsbach mantle	75–100		

This applies both to self-luminous sources and to areas that shine by reflected light.

Table I gives the brightness of a number of light sources. It will be noticed that the oil and gas sources are, as a rule, much closer to the permissible maximum than the electric sources. This makes the use of shades and reflectors or diffusers, with their attendant absorption, less necessary with them.

Street and Public Lighting

The old Syrian city of Antioch apparently is entitled to the credit for being the pioneer in public lighting. Founded about 300 B.C., Antioch was, by 300 A.D., a great city with about 400,000 inhabitants. Concerning fourth-century Antioch, we have testimony that the streets and public places were lighted. Libanius, who lived about 300 A.D., says of his native city:

> The light of the sun is succeeded by other lights, which are far superior to the lamps lighted by the Egyptians on the festival of Minerva of Sais. The night with us differs from the day only in the appearance of the light; with regard to labor and employment, everything goes on well.

In another passage the same writer tells of some riotous soldiers who "cut with their swords the ropes from which were suspended the lamps that afforded light in the night time, to show that the ornaments of the city ought to give way to them."

There had been a few tax-supported lamps in the streets of Paris for 300 years before 1738. In that year there were 6500 street lamps. In Strassburg it was not until 1778 that, by royal edict, street lamps were introduced and a general tax levied to pay for their maintenance. London illuminated its streets in 1812 and Berlin followed in 1826. Dresden saw the first street lamps

in 1828 and Charlottenburg in 1861. Improvements followed in the business, and, at the World's Exposition in Paris in 1900, high-pressure gas was used for illumination. In this country the Welsbach gas mantle was first used for street lighting in 1896.

In Great Britain the gas industry has stuck to its lighting load and developed it technically to the point where it is more than holding its own against electric competition. Particularly is this true in floodlighting. It seems that the Britisher especially appreciates the value of gas in lending color and atmosphere on special occasions, and his first choice is easily floodlighting by gas. On occasions of visits from royalty,[1] celebrations of historic events of towns and cities, and holidays such as Christmas or Easter, the full resources of gas floodlighting are utilized. The units for floodlighting can be equipped with "daylight" mantles if natural colors need to be accentuated. These units are usable either singly or in batteries, and with remote time-controls. The use of "daylight" mantles on the dahlia beds in St. James Park has created much favorable public comment, due to the preservation of the natural colors of the flowers.

Scores of English swimming pools are also floodlighted by gas. The project of floodlighting the Enfield open-air swimming pool was open both to gas and to electrical concerns, and the gas industry secured the contract. The light not only is evenly distributed over the whole surface of water but a system of general lighting has been introduced which makes it possible to read small newsprint anywhere in the arena. Each of the 20 lamps is separately controlled by a special form of distance control device. The effect is described as being very wonderful.

The British gas industry has also achieved considerable success in the floodlighting of churches and cathedrals. The floodlighting of York Minster in 1935 is one of the largest individual installations ever made. The topmost pinnacles of the towers stand out clearly, although they are 200 ft from the lamps on the ground which illuminate them.[2] The illumination of the whole exterior brings out every detail in its beautiful architecture. All this demonstrates the excellence of gas as an illuminant. The lighting also has a delightful softness of its own; it gives a remarkable atmosphere to the building.

In this country, at Ada, Oklahoma,[3] the Southwest Natural Gas Company floodlights its new 60×70-ft building with natural gas. Two Humphrey 3000-cp lights are used.

Nor is the use of gas limited to floodlighting. In Great Britain it is also largely used in schools and for other interiors. Gas is the chief source of illumination for street lighting in towns and cities all over the United Kingdom. The ratio of gas to electric lamps appears to be at least two to one.[3] Two large London gas companies show an annual increase[4] of 2.4 to 7.3 percent in the use of gas for lighting. Another company reports increase of 4.4 percent. The advantage claimed for gas seems to lie in its freedom from sudden failure, and independence, of such factors as thunderstorms and defects in plant equipment. Many contracts are being renewed for periods of from 7 to 10 years and, in some cases, gas is replacing electricity.

Comparisons

The principle of heating carbon to incandescence, used in all early oil and gas lamps, was carried over into the realm of incandescent lamps. In the early days of electric lighting, water gas varying from 22 to 30 cp was a worthy competitor. Yet the improvements in the electric lamp, even in the early years of its use, threatened the illuminating gas business seriously. Then came the Welsbach burner, which reestablished the ascendancy of gas. Later the tungsten lamp appeared and the gas industry seemed again to be threatened. Almost coincidently came the "reflex" burner, or inverted Welsbach (1908). This resulted in a better distribution of light, higher efficiency, and improved durability and strength of mantles. The inverted gas mantle increased the amount of light thrown downward but, in this respect, was soon matched by the horseshoe coil in the gas-filled electric lamp. The inverted mantle also made possible the design of a larger variety of gas fixtures.

The self-contained gasoline or acetylene light-

[1] Stanley Jenks, Gas Age Rec. **77**, 26 (1936).
[2] Stanley Jenks, Gas Age Rec. **77**, 27 (1936).
[3] Gas Age **80**, 21 (Sept. 16, 1937), an editorial.
[4] Sir Francis Goodenough, Gas Age Rec. **75**, 404 (1935); Gas Age **80**, 37 (1937).

ing systems led to the self-contained electric systems such as the Delco and others.

With the coming of the incandescent lamp, which could be turned on or off easily and controlled from a distance, there arose the need for similar control of oil and gas lamps. There was developed a gas lighter made of a strip of pyrophoric; when rubbed with a metallic surface it gives off sparks which can be used to ignite illuminating or acetylene gas, thus avoiding the use of matches. Also, it was found that when a strip of platinum is held in a gas jet for a few seconds the gas is adsorbed so vigorously by the platinum that the latter gets red hot and ignites the gas. The gas industry also succeeded in lighting gas jets at a distance by what is known as the pressure-wave system.

These and other projects, developed largely to meet the growing competition with the electric industry, served not only to encourage the lighting by oil and gas but also to accelerate improvements in electric lighting. The Hylo lamp was developed by the electric industry in response to the appearance of the gas pilot light. The white color of the mantle light was next matched by the light from the daylight bulb (Mazda C_2) and, later, by the white Mazda C_4, which in turn was improved still more by the "daylight" mantle. Even wall switches for gas followed wall switches for electricity; and the clock or pressure-wave system did for gas what the time clock did for electricity. Besides these, many other devices were developed.

We see that oil and gas lamps, first, have initiated a widespread movement to make the public light conscious; second, they have in the main furnished light sources of low brightness; third, they have given people the choice between a wide variety of illuminants; and fourth, they have spurred on improvement among themselves and in the electric industry by the competition set up.[5]

[5] For additional information on oil and gas lamps see the author's Bulletins of the Engineering Experiment Station, Iowa State College: "Illuminating Power of Kerosenes" (No. 37); "Lighting for Country Homes and Village Communities" (No. 55).

Opportunities for the Physicist in the Government Service*

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THE Federal Government probably employs more physicists than does any other single organization. It is difficult to estimate the total number in all departments, but if one considers only those who indicate their profession by holding membership in the American Physical Society there are more than 100, or one in every 25 members of the Society residing in this country. Of these physicists more than half are in the National Bureau of Standards, and one-third are divided equally between the Naval Research Laboratory and the Department of Agriculture, where the Fertilizer Research Division has the largest group. The Bureau of Mines has a considerable number distributed among various stations. Smaller groups are found in the Coast and Geodetic Survey, the Smithsonian Institution, the Washington Navy Yard, the Public Health Service and the Geological Survey.

The purpose of this group of papers is to give some information regarding the opportunities which the young physicist will find in the different branches of the Government service. Since the kind of work done naturally differs greatly among the various agencies of the Government, it may be useful first to summarize the conditions that apply more or less uniformly to all branches of the service. These conditions, in general, may be considered as the mechanics of administration—the matters that are covered by laws, rules and regulations.

* Presented by invitation at the eighth annual meeting of the American Association of Physics Teachers.

Classification of Positions

The scientific agencies of the Government are nearly all in the classified service. This means that the positions are grouped in services, grades and classes established by act of Congress. The act fixes definite ranges of salary for each grade; and the Civil Service Commission has power to prescribe minimum qualifications required of personnel, and to control actions of the various departments and other agencies which affect the classification or grade of any employee.

The law provides for classification of positions into four general services: (1) custodial; (2) clerical, administrative and fiscal; (3) sub-professional; and (4) professional. The sub-professional service includes two general classes of employees. One of these classes consists of laboratory mechanics and helpers, instrument makers and other employees who give services auxiliary to the scientific or professional work but who are not required to have any considerable academic training. For such positions there is provided a line of promotion in the sub-professional service overlapping some of the lower grades of the professional service. The other class of sub-professional positions includes laboratory assistants who are expected to grow in scientific work and to graduate into the professional service. In this class there are four grades. The *minimum* requirement for appointment in the lowest grade is a high school course; for the succeeding three grades, 1, 2 or 3 years of college work, respectively, with specified amounts of physics and chemistry. The entrance salary for the lowest grade is $1020; the maximum salary for Grade 4 is $1980.

In the professional service the grades, salary ranges and minimum requirements are as shown in Table I. The third column is a very condensed statement of qualifications which must be shown before a candidate can enter into competition for a position in a specified grade. For the three lower grades these qualifications are stated in definite terms of degrees and credit hours, or years of training and experience. The "2 yr" or "3 yr" required may be either in research or in graduate study, but for Grade 3 the candidate must have obtained a doctor's degree in order to qualify on the basis of academic work alone. For the higher grades the years of experience specified have little significance, for they are not likely to be determining factors; the essential requirements are necessarily qualitative, but imply recognized standing in some special field.[1]

Table I. *Grades in professional service.*

Grade	Salary	Minimum Requirements	No.*
1	$2000–$2600	Bachelor's degree with specified physics and math.	63
2	$2600–$3200	Degree+2 yr+aptitude for investigation.	43
3	$3200–$3800	Degree+3 yr+professional attainment of a high order.	34
4	$3800–$4600	Degree+5 yr+previous accomplishment of difficult scientific research.	30
5	$4600–$5400	Degree+6 yr+very special qualifications.	32
6	$5600–$6400	Degree+7 yr	29
7	$6500–$7500	Special qualifications pertinent to higher administrative positions.	3
8	$8000–$9000		

* Number in respective grades in 5 divisions of the National Bureau of Standards.

The classification of positions is based upon the character of work to be done. Consequently, the distribution of employees among grades depends upon the kind of work carried on by the organization considered. As an illustrative case, the last column of Table I gives the present distribution in 5 divisions of the National Bureau of Standards in which physicists predominate. The proportion of employees in the lower grades is now abnormally small, but to some extent the relatively large numbers in higher grades are due to the diversity of the Bureau's work and the necessity for having men who are masters of many specialized fields of work. This is possible because, under the classification act, individual scientific work is given at least as much weight as administrative responsibility.

Examinations for Initial Appointment

Appointments from outside the service are all based upon Civil Service examinations for the respective grades. Normally, examinations for lower grades occur annually, and those for higher grades, only when a number of vacancies occur and no satisfactory lists of eligible candidates exist. In recent years there have been relatively few appointments, and lists in all grades have been kept in use for several years. The Civil

[1] General qualifications for various grades and other information regarding personnel are given in *National Bureau of Standards Miscellaneous Publication M152*, which may be obtained on request from the Bureau.

Service Commission has been overwhelmed with work because of the large number of applicants when examinations are given. For example, for examinations in physics announced last August about 1600 applications were received for Grade 1, 500 for Grade 2, and a total of over 400 for the 4 higher grades included in the announcement.

When it is necessary to deal with such large numbers of applicants it is difficult to give examinations that will produce ratings really indicative of the ability of candidates and it is practically impossible to determine suitability for laboratory work. In the lower grades, where actual written examinations are necessary, the Civil Service Commission has been compelled to resort to the short-answer type, omitting questions that call for discussion and give some basis for judging the candidate's ability to formulate and express ideas. This difficulty will presumably be met by a new procedure to be developed under an Executive Order which became effective on February 1, 1939. It provides for examinations in two stages. The first stage is a preliminary rating based upon evidence of training and experience; a limited number of candidates will then be admitted to the second stage, which will include written or practical tests and, when practicable, personal interviews. Under the new order, registers of eligible candidates cannot be used for more than two years unless ratings are reviewed and revised to take account of pertinent experience gained by candidates during that period.

As the final result of its examinations the Civil Service Commission establishes lists ("registers") of persons who have qualified in each of the principal subdivisions of physics—usually electricity, heat, mechanics, optics and sound. Appointments in all departments of the Government are made from the same registers. When an appointment is to be made in a given grade, the Civil Service Commission certifies the 3 persons at the top of the register for the grade and class of work specified. The appointing agency can choose any one of these three; it has no opportunity in general to consider others who are on the register.

A general policy now prescribed by executive order for all agencies is to fill vacancies by promotion within the service, provided there are not distinctly better men obtainable by appointment from outside. The result is that relatively few outside appointments are to be expected in higher grades except when new positions are created which require special training or experience.

Advancement and Conditions of Work

For those who have run the gauntlet of the Civil Service Commission and obtained appointment, advancement may come in two ways. These are (1) administrative promotions within a grade as a recognition of good work, and (2) reclassification to a higher grade by the Civil Service Commission as a result of a change of work, which may be either a distinct change in its character or the assumption of a larger degree of responsibility. The Civil Service in general has no provision for automatic increases in salary, and opportunities for advancement naturally depend largely upon conditions such as the size and growth of particular organizations. In general, however, the capable scientific worker has little need to fear stagnation in the Government service; a definite policy of encouraging promotions by transfers between branches of the service is being developed to counterbalance the limitations inherent in small branches.

In comparing salaries with those obtainable in other employment, one must, of course, consider what the money will buy, and this depends somewhat upon the locality. The classification shown in Table I applies primarily to service in Washington, where the cost of living is relatively high.

Less tangible factors are the facilities and opportunities for doing work of an interesting and inspiring kind, the chances for gaining recognition through publication of one's results, the personal associations which one will have, and the opportunities for going out into better positions. Naturally these factors differ somewhat among the different departments, but in general the conditions in respect to them are good.

With regard to personal privileges such as leave with pay, the Government service is intermediate in advantages between educational work and industry. Twenty-six working days of

leave per year are allowed, and such leave can be accumulated up to 60 days. In addition, in case of illness 15 days per year are allowed, and this sick leave is cumulative up to 90 days. The normal working week prescribed is 39 hours; but, as anyone who carries on scientific work knows, the significance of that number is chiefly that it indicates the hours to be put in at a specified place rather than the number one must work at his calling. In the Government service, as elsewhere, there are enough problems to be met so that the important question is usually how much time one can find to work at the things he wants to do.

Physics in the National Bureau of Standards

The work of the Bureau of Standards includes so many different activities that they can hardly be listed here. A general outline of the work, including an organization chart showing the subdivisions, has recently been published by the Director.[2] The diversity of the work and the extent of specialization are illustrated by the fact that there are 40 sections, or working units, in the 5 divisions organized along the lines of the customary subdivisions of physics. Physicists also have an important part in the work of many sections in the 3 divisions that are devoted more largely to technologic problems.

Practically all sections of the Bureau have some routine or service functions to perform, but the proportion of time spent on such work in comparison with research or development varies greatly. For the Bureau as a whole the classes of work on which most time is spent are research on physical constants and properties of materials, and testing of supplies and materials for the Government. Somewhat more than 20 percent of the expenditure for salaries goes into each of these two classes. Maintenance of standards, research on standards and methods of measurement, and development of methods and equipment for testing in combination take another 20 percent, information and consulting service for the public and the Government, 15 percent, while 4 percent is spent in calibrating instruments and standards for the public.

The Bureau's work ranges from the structure of atoms to the behavior of bridge members, from the precise weighing of the forces between electric currents to the calibration of railroad track scales, from the production of liquid helium to the casting of metals, from the study of flow in plumbing systems to the measurement of cosmic rays and ultraviolet radiation in the stratosphere. Such diversity of work makes it possible to adjust assignments to a considerable extent in accordance with individual aptitudes of members of the staff; but a very large part of the work is naturally experimental, and men who are skilful in handling apparatus, as well as fertile in ideas, are always in demand. Ability to design equipment and to make simple drawings are added qualifications much to be desired, but an equally important one is the ability to make a clear presentation, either oral or written, of results obtained.

The Bureau is fortunate in having close relations with those engaged in academic or "pure" physics, on the one hand, and with those applying physics in industry, on the other. For many young men its work has consequently been the transition stage from college to industrial employment; and, so long as the flow of personnel is not excessive, this is recognized as an appropriate service furthering the application of physics in industry. In its own work, however, the principal aim of the Bureau is to contribute to the fundamental knowledge on which engineering and modern industry are based rather than itself to make the practical applications.

[2] L. J. Briggs, J. App. Phys. **8**, 298 (1937). A series of articles giving more details was published in the *Scientific Monthly* **36** and **37**, various numbers, March to November (1933).

Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keeps faithfully busy each hour of the working-day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out.—William James, *The Principles of Psychology.*

The Physicist in the Coast and Geodetic Survey*

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U. S. Coast and Geodetic Survey, Washington, D. C.

THE United States Coast and Geodetic Survey has been primarily a technical organization ever since it was chartered by Congress in 1807. In seeking an outstanding man to be its first superintendent, President Jefferson found Professor William Hassler, a noted Swiss engineer and surveyor, at that time instructor in mathematics at the United States Military Academy. Hassler knew his value and asked for a salary of $5000. President Jefferson protested, saying that this was as much as the salary of his Secretary of the Treasury, to which Hassler replied, "Well, any President can make a Secretary of the Treasury but only God Almighty can make a Hassler!" Hassler laid a solid foundation for scientific truth and accuracy when he brought the standards of length, mass and volume from London and Paris himself, unwilling to entrust such precious objects to anyone else. This tradition of accuracy has been maintained throughout the 130 years of the Survey's existence. It is a tradition of the Service that no published results have ever had to be repeated because of error.

While the applications of physics are used to a large extent, not many employees have the official title of physicist. Several years ago, when a former Director was asked for physicists as assistants, he said, "I cannot ask Congress for physicists here in the Survey, for the answer would be, 'You need engineers and not physicists as the latter all belong in the Bureau of Standards.'" Consequently, many whose training was principally as physicists are listed as engineers, observers, magnetic observers, etc. My personal case was to be admitted to the Civil Service with the rating of Radio Engineer, but when the appointment in the Coast and Geodetic Survey was made the rating was changed to Electrical Engineer. I have known of three separate cases where men with the rating of Physicist at the National Bureau of Standards were transferred to the Survey with the title of Electrical Engineer. One of these was then transferred to the Naval Research Laboratory with the title of Physicist and finally back to the Survey with the title of Electrical Engineer.

These examples are given to illustrate how a physicist may have to change his title almost chameleon-like, although at heart and in mind and training he is still a physicist under the simple definition which I used that "physics is the science of how and why things happen."

Much of the work of the Coast and Geodetic Survey has been so standardized that some portions appear to consist only of routine measurements. Yet physical principles were used in the development of the methods; and it may well happen that a young observer of keen mind and sound training in physics will suddenly have a vision of how those routine measurements, almost monotonous in their similarity, can be automatically recorded in a manner which is better, more accurate and less expensive than, for instance, the humdrum method of counting

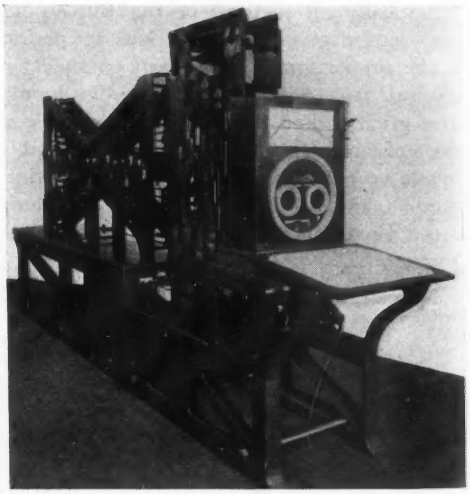

FIG. 1. Tide-predicting machine.

* Presented by invitation at the eighth annual meeting of the American Association of Physics Teachers.

the number of swings of a pendulum. Imagine counting 1600 swings of a pendulum and being sure you didn't miss just one! It is well to have all processes critically examined from time to time by a physicist to see if the method can be improved. Quite often the inexperienced but carefully trained physicist sees a possibility of improvement which the so-called expert may not recognize because he is so familiar with that particular process and it has been so long accepted as the best possible method. While the Coast and Geodetic Survey thinks it is using the best methods available in all its operations, if a better method is developed it will be adopted immediately, provided funds are available to make the change.

Even the data of routine measurements may occasionally require the assistance of a physicist to interpret the results, and provision has been made in legislation to render it possible to employ, temporarily, a physicist for such work.

Going into some detail concerning the different

FIG. 2. A gravity station.

divisions of the Survey, we note that the Division of Tides and Currents presents the application of physics in the hydraulics of the oceans. Currents may be ever changing, both in direction and speed, retracing, often, an elliptical curve of directions and force. Tides, created primarily by the gravitational forces of the moon and sun but influenced by local conditions, may reach an

FIG. 3. Triangulation station in Alaska.

extreme height of 48 ft or, in simple cases of interference of 2 nearly separate bodies of water, rise and fall only 15 in. in 24 hr. Yet the tide-predicting machine (Fig. 1) will, when part or all of its 36 components are set for any particular place, draw the actual curves for any period of time in the future, marking the time of high and low water, even tracing the curve for the 29th day of February in leap years.

The measurement of acceleration due to gravity is a subject familiar to every student of elementary physics. The Division of Geodesy makes 200 gravity measurements yearly (Fig. 2), in error by only 1 part in 10^6, by swinging a pendulum in a vacuum for 6 hr and recording the swings on a chronograph on which Arlington time signals also are recorded. In the measurement of length in triangulation (Fig. 3), the temperature of the tape, under constant tension, and the linear expansivity even of the Invar steel must all enter into the computation.

Refraction of light brings in the physics of the air in all measurements of angles and also in leveling. It may be recalled that a few years ago this division determined, with great precision, the base lines of Pasadena and Santa Anna for the measurements of the speed of light.

Physics really comes into its own, however, in the Division of Terrestrial Magnetism and Seismology. Five different magnetic observatories—located at Cheltenham, Maryland; Tuc-

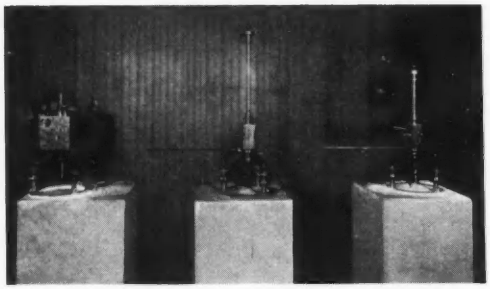

FIG. 4. Recording magnetic instruments at Cheltenham.

son, Arizona; San Juan, Puerto Rico; Honolulu, Hawaii; and Sitka, Alaska—maintain continuous, controlled records of the three components of the earth's magnetic strength of field. Of these five, Cheltenham is the most important, serving as a world standardizing station (Fig. 4). The magnetic data collected at these observatories are scaled and tabulated and then sent to Washington where they are checked, processed and printed as separate publications for each observatory. In accordance with the Coast and Geodetic Survey's policy of always endeavoring to cooperate with other groups, these observatories make other records, such as continuous cosmic-ray observations at Cheltenham, and observations of earth currents and potential gradients of the air at Tucson.

It is of interest to note that the recording magnetic variometers are also affected by earth movements and consequently record earthquakes. Partly for this reason, the study of earthquakes was assigned to this division. Many contributions have been made to the design of recording seismographs and accelerometers; and the Division acts as the world's clearing house in calculating the epicenters of earthquakes from data collected by *Science News Service*. Twenty seismograph recording stations are maintained largely on a cooperative basis; and, since the ideal of seismology would be to predict earthquakes with sufficient advance warning to prevent at least some loss of life, work has been started on the acoustic listening and recording of earth sounds. On being questioned about the possibility of such results, my reply was that, with good acoustic pick-ups and sufficient amplification, it would be surprising if some earth sounds would not be discernible and that with experience it might be possible, from the nature and intensity of these sounds, to predict the probable outcome. Some 20 physicists are employed in this division, although none has that title officially. Many are classed as magnetic observers, although in the Civil Service examination mathematics counts 30 percent, physics, 30 percent, and magnetism and seismology, 40 percent. Since magnetism is physics, and seismology is an application of complex wave motion, physics may be said to have a weight of 70 percent in the examination for the position of magnetic observer.

In the Division of Hydrography and Topography, which makes the hydrographic surveys for constructing charts, physics is applied in all its traditional branches. Sound, electricity and magnetism have entered this field so extensively in the last 15 years that the entire art of hydrography has been revised, giving precision depth measurements beyond the fondest dreams of earlier hydrographers. Moreover, the speed of measurements has been doubled and the accuracy of location of the surveying ship's

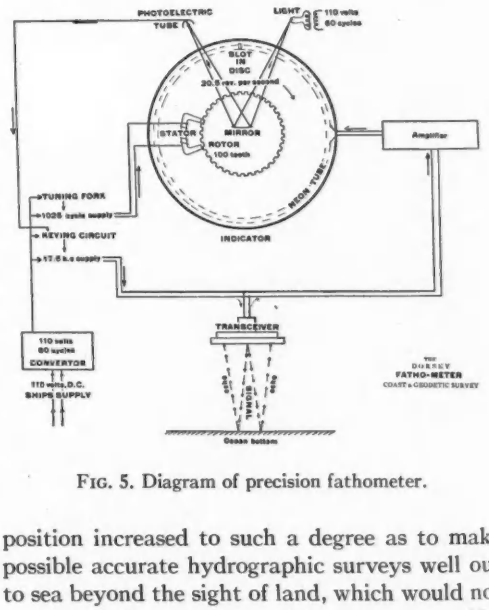

FIG. 5. Diagram of precision fathometer.

position increased to such a degree as to make possible accurate hydrographic surveys well out to sea beyond the sight of land, which would not even have been attempted 10 years ago. Yet our feeling is that we have merely scratched the

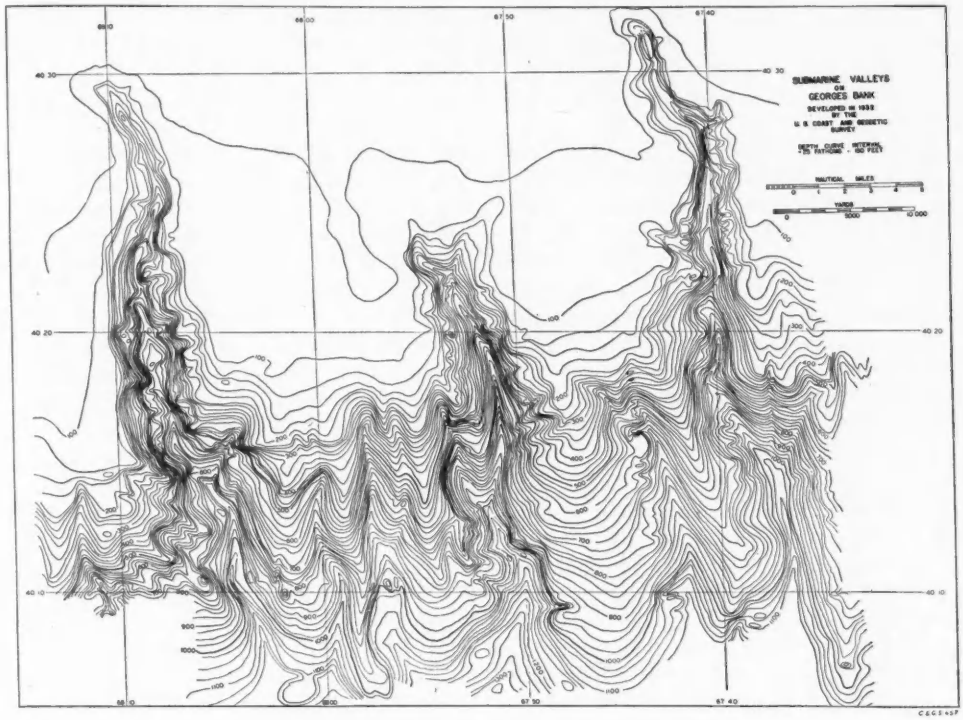

FIG. 6. Oceanographic contour lines on Georges Bank.

surface in the application of physics to these interesting problems.

In the latest type of echo-sounders as developed by the Coast and Geodetic Survey (Fig. 5) the time-measuring device is run by a tuning fork; supersonic signals are sent by a recurring passage of light across a photoelectric tube, and a flash of duration 2 to 3×10^{-6} sec in a stationary neon tube indicates the depth 20 times/sec for shallow water, the apparatus operating with no moving contacts and no governor. It is so precise that soundings taken at anchor by this instrument 27 mi offshore in the Gulf of Mexico made a record of the rise and fall of the tide with no deviations of more than 0.1 ft from the smooth tide curve. The precision of depth and position is such that topographic curves can be plotted of the ocean bottom in thousands of feet of water, showing that such curves occur there in just as natural a manner as similar curves on dry land (Fig. 6).

In determining the ship's position by radio-acoustic ranging, the study of subaqueous acoustics has shown that, in water, sound may be reflected, refracted and diffracted, and in traveling distances of 50 mi or more reaches its destination only by refraction from top and bottom almost as light is reflected from front to back in a long strip of glass (Fig. 7). With the ocean as a laboratory it is fascinating to listen for the radio return of a bomb signal from sono-radio buoys so far away that 50, 70 or 100 sec may elapse after firing, even though the speed is 1500 m/sec. Such buoys, with the ocean as a constant temperature bath to keep the frequency

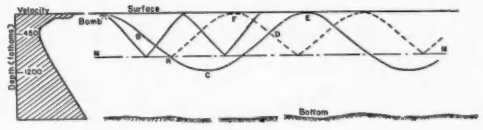

FIG. 7. Propagation of sound in deep sea water.

of the radio signals constant, operate as long as 50 days without attention. They contain an audioamplifier for the bomb signal and a radio transmitter that operates automatically whenever it receives the sound of the bomb.

Extensive research on both the Pacific and Atlantic oceans has been carried out in an effort to learn more about the propagation of sound through sea water. The expense of running the surveying ships is so great—from $500 to $1000 per working day—that any experiments which may speed up the progress of hydrographic surveying by only a small percentage are a financially paying proposition.

Of interest is the fact that primary distances between survey buoys are measured with a steel piano wire run from a reel of 140 mi of such wire and played out under constant tension over a measuring sheave. From these measurements and from bomb signals with radio returns from the sono-radio buoys, the speed of sound in the water is determined. In general, the results by radio-acoustic ranging are seldom off more than 1 part in 600 and often as little as 1 part in 1000, even though distances as great as 150 mi have been involved in the triangulation.

Echoes in air from your hand or from a postage stamp at a distance of 3 ft and in the ocean from the edge of the Gulf Stream or at the junction of fresh and salt water are only two of the hundreds of fascinating physical phenomena I have come across during my connection with the Survey. The work is so interesting that I have often said that I have done nothing but play for the past 13 years and have been paid for it.

Now for a few statistics. The total number of employees in the Survey is about 1080 and this includes the crews on the ships, etc. Of this number, 525, or over half, are first selected through Civil Service. There are 171 commissioned officers from the rank of Admiral, at the top as Director, to that of Ensign. These officers do practically all the surveying. They are specially selected from graduates in civil engineering from recognized first-class American colleges. While primarily civil engineers, all have studied college physics and some have shown remarkable aptitude in the application of their college training in physics as shown by their ability to apply physical principles to the surveying operations. All at some time in their careers have had field training in tides, currents, geodesy, magnetism, hydrography and topography. I might mention that one of my former students in Physics 10 at Cornell University is now one of the outstanding commanding officers in the Survey. Besides the commissioned officers, about 80 men have one or more college degrees and have studied physics, so that at least 250 have had courses in college physics. These 80 civilians under Civil Service receive an average salary of approximately $3200. Now this does not mean that physics students stand a good chance of getting a $3200 job in the Coast and Geodetic Survey this June. Far from it. The entering pay may be $1800, and there are seldom any vacancies. Advance is slow and all positions are filled through the Civil Service Commission. First, an examination given by the Commission must be passed to get on the list and then it is necessary to wait for a vacancy. But as a rule the incumbents of these positions are well satisfied and contented; many having been in the service for 30 or 40 years. It is a good life work.

From past experience in commercial work, I wish you would teach your students that the problems of life are not found in the books. The fundamentals must be so well learned that when new problems are encountered a solution may be obtained through the application of those concepts and principles. Also please teach your students that even in Government work one cannot continue to experiment on one problem indefinitely. Generally there is someone who will continue to urge a person to produce results that will complete a problem. This is well, for with one problem solved and out of the way one has the joy of starting a new project, possibly more difficult and probably more interesting. And the supreme satisfaction of seeing in actual operation the successful results of a completed problem is almost as great as the joy of teaching physics.

On the Physicist in the Government Service*

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IN A forward-looking organization concerned with present-day activities, scientific research plays an important rôle. A small institution with limited capacity may find that the cost of research is high and in the nature of a luxury, sometimes unobtainable. In a large institution, however, research yields results which are so valuable in respect to the cost that it is regarded as a desirable necessity. Thus it is that our government research activities have undergone a moderate and steady augmentation. As an illustration, we may consider an organization with which I am familiar, the United States Naval Research Laboratory. The Laboratory was established in 1923 with a scientific staff of about 50 men. It has experienced an approximately uniform growth of about 7 men a year to attain the present staff of about 150. During this period the total Naval establishment expanded but little and therefore the importance of the Research Laboratory relative to the entire Navy has increased. The increase cannot continue indefinitely; saturation must be reached eventually. The Laboratory now uses roughly 0.2 percent of the Naval funds, although, of course, it does not absorb by any means all of the funds allotted to research by the Navy. Of the Laboratory staff, about one-fifth of the numbers are classified as physicists and have had training in physics. They are distributed through the divisions of chemistry, metallurgy, radio, sound, physical optics, mechanics and other branches.

In discussing the physicist in the government service, one is troubled by the lack of an exact exposition of just what physics is and what a physicist does. In the confines of the university there is no difficulty; a physicist is a sojourner in the physics department. What impression is produced on a high official of the police court when the innocent traffic offender writes himself down as "physicist," I am unable to say. I like the remark that a physicist is one who learns all the chemistry, metallurgy, mathematics, meteorology and geology that he can. We may admit the vagueness and be content with the supposition that a physicist is one who is able to tackle almost anything. We may perhaps cling to one characteristic of the work of the physicist—it is nonroutine. The moment the work becomes routine it usually is no longer physics. A physicist devises instruments to discover and to investigate phenomena of the earth's magnetic field, of the atmosphere, of radio waves, of sound waves. The investigations are carried on, however, by terrestrial magneticians, meteorologists, radio engineers, acoustic engineers. Perhaps no one is more surprised than the student who emerges from his cast, or shall we say chrysalis, of physics to discover that he is not a physicist but a metallurgist, an oceanographer, an aerodynamic expert or an investigator of optical glass. Cosmic rays and nuclear physics have yet to produce their professions of barytron—or is it neutretto —engineer and nuclear chemist.

From the *Reports of the United States Civil Service Commission* through 1937, data were gathered which are presented in the curves of Fig. 1. Curve 1 comprises persons in all branches of the government service who have the classification of *physicist* plotted as numbers in each salary bracket. Practically every one in this classification received his or her education in the physics department of a college or university. In curve 2 are plotted numbers of persons in certain classifications that may include a considerable proportion who were trained in physics. The classifications were those of *astronomy*, *mathematics*, *metallurgy*, *meteorology*, *oceanography*, *nautical science* and *technology*. The total of curves 1 and 2 is given in curve 3. The point on curve 2 for the salary range below $2000 may be ruled out of the present consideration; it is made up largely of young high school graduates in services of the Weather Bureau for whom special training in physics is not essential. This is also true, but to a lesser extent, of the points of curve 2 for the salary range $2000 to $3000.

The total number of persons in curve 1 is 303,

* Presented by invitation at the eighth annual meeting of the American Association of Physics Teachers.

in curve 2 is 885, and in curve 3 is 1188. Without more complete investigation the exact number of the 1188 who were trained in physics cannot be ascertained; it is probable that 500 were so trained. There are undoubtedly physicists in other categories of the government service who have not been included in the curves of Fig. 1. It would appear not far from the truth to conclude that in the government service there are today 500 people with a major education in physics and working in physics, with a salary distribution approximating that of curves 1 and 2. Detailed examination of government records would be necessary to discover how many positions are vacated and filled by physicists each year.

Physicists are widely scattered through the various government agencies, such as the National Bureau of Standards, the Coast and Geodetic Survey, the Bureau of Mines, the Weather Bureau, the Army, the Navy, the Patent Office, the Department of Agriculture and the Treasury Department. The types of work are so varied as to defy complete classification except in the most general terms, the variety being inherent in the wide scope of the field of physics. The work is, on the whole, nonroutine, investigatory and experimental in character. It consists in attacking one problem after another, the problems being diverted to the men, let us hope, most able to effect a solution.

I am unable to think of any important element wherein the work of the physicist in the government differs from the work of the physicist in any nonacademic organization. The government problems are essentially "applied" in character —for the purpose of avoiding or curing an existing difficulty, of improving an existing situation, or producing a benefit somewhere and somehow. The problems may be either immediate or farsighted.

Obviously, in the process of seeking a solution, one may be led far afield and the investigation may assume a very "pure" aspect. But the purpose of the research is at all times toward a result of possible benefit, and therefore the appellation "applied" is appropriate. This is in contrast with the research in a university. There the point of view is, or I think should be, as free as possible and the research may be as "pure" as possible,

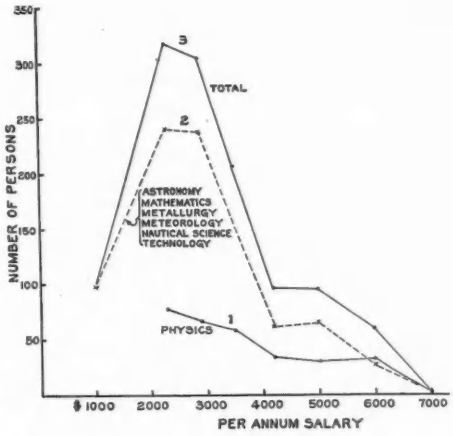

FIG. 1. Number of employees in each salary bracket.

although there is no impelling need that it be so. Any problem may be undertaken, whether it be directed toward the discovery of a new fact, the more exact measurement of a doubtful quantity or the testing of a theory, without ulterior motive other than to obtain as true and as numerically correct an answer as possible. The pure and applied aspects of scientific endeavor are not conflicting but are supplementary and, together, form a harmonious whole. Each is dependent upon the other; neither could long exist without the other.

This dual aspect is perhaps fully appreciated by the undergraduate and graduate teacher. In his academic surroundings he engages in whatever research he will, being limited only by available funds, geography, and his intellectual and physical strength. He instructs in the broad principles of physics and in the details of his particular field. He directs his students to those problems in which he is experienced and in which the student may have some expectation of success. He knows, however, that many of his young scholars will leave the circumscribed region of academic freedom to enter the wide sweep of nonacademic restriction. These young men and women soon discover that their physics is no longer an end in itself, but is working toward some other end, whether it be the x-ray determination of the crystal structure of a broken propeller or tracking down adulterants with the aid of ultraviolet spectroscopy. This

calls for a nice balance on the part of the university professor, in order that he may instruct unceasingly by lecture and experiment in the purest fundamentals of physics, and at the same time bring out in proper measure the view that the application of physics to human problems constitutes the very leaven and *raison d'être* of the subject.

There is no special training in physics required for government service over and above the education now offered in the academic curriculum. Naturally, the instruction should be thorough, vivid and up-to-date. The degree of Doctor of Philosophy is undoubtedly a factor in advancement, probably to exactly the same extent that it is in a college or university. To write good English is a ubiquitous desideratum; it can be learned, but I do not know whether it can be taught. If there is a suggestion to be made, I would say teach the hard things, both theoretical and experimental. I still remember the hours I spent with Webster's *Dynamics of a Particle*—the volume contained such a welter of letters, numbers and integral signs; but Lorentz and Sommerfeld went the better for it. Rayleigh would make a splendid entrée for Dirac, if there were opportunity for both. One who has adjusted for the first time a galvanometer or electrometer of high sensitivity, especially if it is a little dented as most of them seem to be, and has really made it work and yield the answer to his question, has gained a touch of the experimental skill and intellectual confidence which is the stock-in-trade of the experimental scientist. And arithmetic—nine-tenths of the drudgery of many a physical problem lies in the computations. Drive home the slide rule, logarithms and significant figures. The school or the graduate student who multiplies one six-digit number by another exhibits a vigor that is admirable and completely wasted. This is small chaff but may be gritty unless swept away.

The young physicist entering the government service is almost certain to work under supervision which may be close or distant. His problem may be small and self-contained or may be part of a larger problem. He may feel constrained and impatient with certain processes which seem deliberate. But the constraints and processes cannot be said to be peculiar to the government service. They are inherent in the pattern of any large organization. The following considerations may give him encouragement. Whenever one hears of an interesting development emanating from an institution and digs down to ascertain the ultimate source or cause, he ends by finding a man. He discovers a man, perhaps a young man, who has done something; some individual who has shown the divine spark, the clear-headed insight, the reduction to simplicity, the apt fitting of scientific knowledge to the case in hand. Then, there is the remark of a mature physicist who was asked how he would accomplish a certain difficult problem. It really was hardly a problem at all, but more in the nature of a wish. "Sure," he said, "that is easily done. Give me one good man."

In conclusion, the physicist can find in government service a fitting career which offers a range of endeavor sufficiently challenging to intellectual satisfaction and to scholarship of a high type. At times he is very close to the world of affairs, but not always too pressed upon by outside circumstances.

It is not a dead world which we study; we study the dreams of men, dreams which have materialized into a magic world. Our study is inherited from the contemplations of a Greek philosopher, the vision of Newton, the experiments of Faraday—from generations of scientists inspired to seek truth in nature. I do not know what you will see in the workings of an electric motor, in the wonder of the snow crystal, in the story of the atom, in the unity of nature, in the meaning of space and time. Dreams are not things for words; the beauty which you find will depend upon the quality of your imagination; but unless you learn to see a great wonder in these things it is not physics which you are studying but a dreary subject which died aborning.—JOHN A. ELDRIDGE, *College Physics.*

Agricultural Physics*

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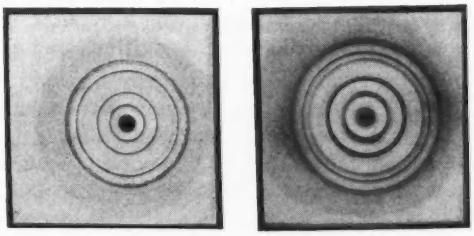
APPLIED physicists are employed by the Department of Agriculture. This does not mean that training in, and a knowledge of, fundamental or academic physics is not necessary. It is not only necessary but very important that the applied physicist keep up with modern experimental and theoretical physics, especially as related to atomic and molecular structure and the active or excited states of atoms and molecules. Relatively few of us, about 25, in the Department of Agriculture have the title of, and are listed professionally as, physicists. Those employed as such are investigating soils, fertilizers, agricultural products such as foods, forestry products and textiles. Many more, a few hundred, are known and listed professionally as meteorologists, physical chemists, technologists, engineers and conservationists.

The importance of the physics of soils has been recognized for a long time; a division of soils was created in the Weather Bureau about 1893. Dr. L. J. Briggs, Director of the National Bureau of Standards, made basic and fundamental contributions to the subject while he was employed by the Department of Agriculture. The study of soils consists of physical investigation of soil types, soil composition, soil minerals and soil solution; also of the physical properties of soils in relation to formation, texture, erosivity and productivity. Many of the research problems falling within this field have been concerned with the moisture relations of soils and the physical properties of soil colloids. The centrifuge method has played an important rôle in the separation of soil particles and a determination of the grain or particle size distribution. It is used extensively to secure colloidal soil fractions for physical and chemical tests. The centrifuge is employed effectively to determine the moisture equivalent of soils. High intensity supersonic waves also have been used with some success in the dispersion of soil suspensions. Measurements of the dielectric constant of soil-water systems are being used as an indicator of changes of state as regards freezing and melting.

Microscopic, x-ray and electron diffraction methods are used in identifying the clay minerals and determining their molecular and atomic arrangements. Sedimentation experiments show that a considerable portion of the soil is submicroscopic in dimension and in fact approaches colloidal material. Diffraction patterns show that they are not indefinite amorphous mixtures but rather contain only a few characteristic compounds. Three distinct types of minerals are often present—those related to kaolinite, to montmorillonite, and to a mica-like mineral containing potassium. From diffraction patterns similar to Fig. 1 and other information the space models of the clay minerals are deduced and constructed[1] as shown in Fig. 2(a) and Fig. 2(b). The montmorillonites, which form the so-called bentonites, have the unusual property of swelling when placed in water. The water goes between the layers of these units as the result of the small attractive forces and, in so doing, it increases the stability of the lattices. The difference between these two structures, we believe, is definitely related to the water-retention properties of the respective clays.



(a) (b)

FIG. 1. Electron diffraction photographs taken from (a) kaolinite and (b) montmorillonite.

* Presented by invitation at the eighth annual meeting of the American Association of Physics Teachers.

[1] These models were constructed from strips of colored Cellophane held together by metal fasteners in conjunction with closed spheres. They were made by Mr. John Rannells, 174 West 89th St., New York, N. Y.

By x-ray diffraction, the structure of apatite, the essential mineral of phosphate rock, $Ca_{10}(PO_4)_6F_2$, was determined. Fig. 3 is a photograph of an atomic model of this structure. The commercial phosphate rock deposits in the United States have the apatite structure, and fluorapatite is the predominant constituent. In 1937, 3,954,239 long tons of phosphate rock were mined, largely in Florida, Tennessee, Idaho and Montana, with a wholesale value f.o.b. mines of $12,964,193. The processed rock furnished the major portion of our agricultural phosphates as well as an export commodity.

The structure of alunite, $KAl_3(SO_4)_2(OH)_6$, was determined by x-ray diffraction, and the model shown in Fig. 4 was constructed on the basis of this structure. Extensive deposits of this mineral occur at Marysvale, Utah. It is a potential source of both potassium and aluminum salts. At present our agricultural potash comes from the water-soluble salts found in New Mexico and California and in imports from Europe.

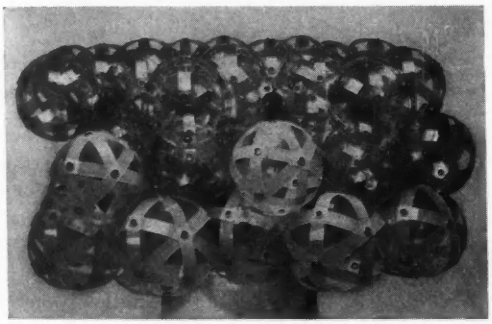


FIG. 2(a) Photograph of the space model for the clay mineral kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$).

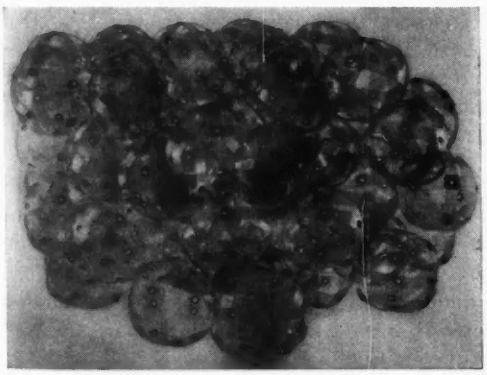


FIG. 2(b). Space model for the clay mineral montmorillonite ($Al_2O_3 \cdot 4SiO_2 \cdot nH_2O$).

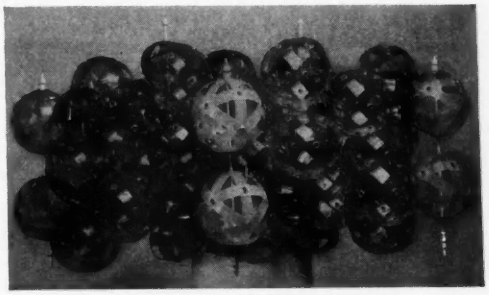


FIG. 3. Space model of apatite [$Ca_{10}(PO_4)_6F_2$].

We are all familiar with the increasing use of the spectroscope in research; this is particularly true for agricultural problems. In our nitrogen fixation studies, a spectroscopic method for studying the nitrous acid equilibrium, involving absorptions due to nitrogen trioxide (N_2O_3) and nitrous acid (HNO_2), has been evolved. Thus, by the spectroscopic investigation of the components of the system NO, NO_2 and H_2O, the thermodynamics of gaseous HNO_2 is being studied. In this case the ordinary chemical methods are not applicable. Investigations by spectroscopic methods are being made on mixtures of the nitrogen oxides and ozone, a gaseous oxidizing agent which converts the lower oxides of nitrogen to nitrogen pentoxide (N_2O_5) and even, to some extent, to a higher oxide (NO_3).

The use of the spectroscope in determining trace elements in soils, fertilizers and food products is of increasing importance. When chemical methods fail, an analysis of the plant ash often makes it possible to follow the occurrence of these trace elements from the soil or fertilizer used to the amount assimilated by the plant. A study of the infra-red spectra of organic molecules with a view to determining certain structural properties of the molecules, for example, the hydrogen bond, is giving some definite and promising results. The transmission properties of glass and other food containers to radiations which produce rancidity have been investigated by means of a quartz monochromator. The spectroscope has considerable pos-

sibilities in problems pertaining to the Food and Drug Administration.

The physicist or biophysicist should be interested in a number of problems studied by the Bureau of Animal Industry. One problem investigated is a calorimetric study of the factors concerned in the incubation and hatching of chickens. For a recent year it was estimated that the failure of 700,000,000 eggs to hatch represented a monetary loss of over $14,000,000.

The physical properties of natural fibers, wool, cotton and cellulose, as well as synthetic fibers such as rayon, and the use of these in textiles, are primarily in the field of physics. We have at least four textile physicists in the Bureau of Home Economics and a number of cotton technologists in the Bureau of Agricultural Economics who are investigating problems relating to cotton standards and cotton utilization. In the Forest Products Laboratory of the Bureau of Forestry, Madison, Wisconsin, physicists are engaged on problems related to timber physics and wood technology.

The physicist or biophysicist will, no doubt, be called on to take an increasingly active part in the solution of many of the problems arising in plant growth or plant metabolism, such as the rate of chlorophyll production, photosynthesis and the effect of x-rays in developing new varieties. A detailed study of the basic physical information contributing to the more complicated biological systems is being given increasing attention by the Department of Agriculture. The Smithsonian Institution, though not a part of the Department of Agriculture, has for some time carried on solar radiation studies with a view to the utilization of the sun's energy. The Smithsonian's division of radiation and organisms has physicists working in cooperation with plant physiologists on growth factors of plants under selected or monochromatic illumination and on other problems closely related to agriculture.

The meteorological physicist, of which the U. S. Weather Bureau has, on the average, about 35 in Washington and 250 in the field throughout the country, is rendering service with which the reader is familiar. Taking the narrower meaning and adhering to the modern tendency, we may restrict meteorology to the phenomena that are

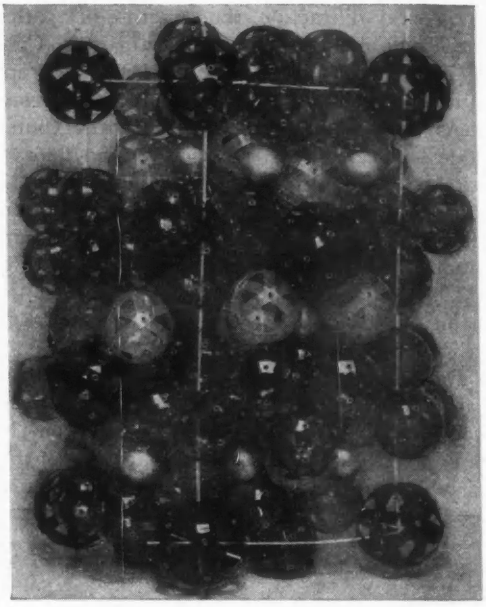


FIG. 4. Space model of alunite $[KAl_3(SO_4)_2(OH)_6]$.

directly involved in the weather, excluding even other atmospheric phenomena and thus drawing more or less of a distinction between *meterology* and *climatology*. Meteorology, therefore, may be regarded as an important branch of physics, to which many of the most notable contributions in the past have been made by the physicist. Weather is essentially a dynamic and thermodynamic phenomenon. The so-called "air mass analysis" method has furnished a practical framework for the development of a truly physical approach to the problem of weather interpretation. The value of the "air mass analysis" is becoming increasingly important in weather forecasting.

Solar radiation studies are of fundamental importance in meteorological work, since the energy from the sun is almost entirely responsible for the maintenance of the physical activities that determine weather and climate. The continuous records of total solar and sky radiation intensities on a horizontal surface are the basis of the study of solar climatology.

Mathematical physicists scattered throughout the service make valuable contributions to the

analysis of data, deductions therefrom and the determination of further experiments. Work of this type constitutes a very important aspect of applied physics that is often neglected.

In addition to the lines of work previously enumerated, in which applied physics especially serves agriculture, there are many other agricultural projects—water conservation, soil conservation, etc.—in which engineers, technologists and conservationists are engaged.

Many of the problems arising in physical chemical processes, such as catalysis, high pressure and high temperature properties of gases, vapors and solids, probably can best be solved by the cooperative efforts of physicists, chemists and engineers.

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Gas Viscosities by Capillary Flow

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MEASUREMENT of gas viscosity by a capillary flow method involving simple apparatus may be accomplished with a fair degree of accuracy. Anderson[1] has described a method in which gas is allowed to flow through a capillary tube from a constant-volume reservoir. The coefficient of viscosity is measured in terms of initial and final pressures, the time interval and dimensions of the apparatus. The apparatus in the form to be described furnishes the student with an application of Poiseuille's formula, provides practice in the use of thermoregulators and permits measurement of the coefficient of viscosity of air with sufficient accuracy to check the Sutherland formula[2] expressing its dependence on temperature.

[1] A. Anderson, Phil. Mag. **6** 42, 1022–3 (1921).

[2] *International Critical Tables* (1929), vol. 5, p. 1.

The essential apparatus is sketched in Fig. 1. An adjustable mercury column A is connected by flexible tubing and a short section of glass tube with a ground glass joint to an inverted flask V of volume 300 ml. In an opening in the side of the glass tube is inserted one end of a capillary tube C. The other end of the capillary is fitted into a larger tube provided with a stopcock S. Air can be compressed in V by raising column A, and allowed to escape through the capillary for a time t. The volume of gas in the flask is kept constant by adjusting column A to keep the mercury level at the fiducial mark F.

Poiseuille's formula for the flow of a liquid in a cylinder,

$$Q=(\pi R^4/8L\eta)(P_1-P_2), \qquad (1)$$

gives Q, the volume of fluid passing any cross section in

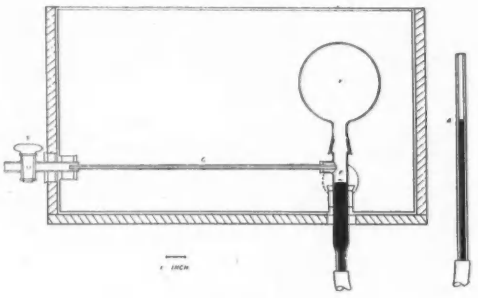

FIG. 1. Diagram of apparatus.

unit time, in terms of the radius R, the length L, the difference between the pressures at the ends, P_1-P_2, and the coefficient of viscosity η. In the case of a gas the rate of flow past any section depends on the pressure there. Eq. (1) may, however, be applied to an element dx of the tube and then integrated. If one does this and solves for the coefficient of viscosity, there results the relation[3]

$$\eta=(\pi R^4/8LV)Pt\Big/\log_e\left(\frac{p_2+P}{p_1+P}\frac{p_1-P}{p_2-P}\right), \qquad (2)$$

where V is the volume of the flask, p_1 and p_2 are the pressures at the entrance of the capillary at the beginning and end of t seconds of observation, respectively, and P is the atmospheric pressure.

This method has the advantage that the end-effects are negligible and that gases other than air can be tested. There are no surface tension corrections, which are considerable in the otherwise simpler U-tube method.[4]

To permit measurement of coefficients of gas viscosity at different temperatures, the flask and capillary tube are immersed in water contained in a copper-lined wood box mounted on an adjustable stand. Two glass windows cemented over circular openings in the sides of the tank permit observation of the fiducial mark F, a small lamp being placed behind one window to provide illumination.

The temperature of the water bath is adjusted by a knife-type immersion heater, a bimetallic thermoregulator and a stirring motor (Fig. 2).

[3] See, for example, B. L. Worsnop and H. T. Flint, *Advanced Practical Physics for Students* (1923), pp. 174–7.
[4] D. Roller and D. Wooldridge, Am. Phys. Teacher **4**, 218 (1936).

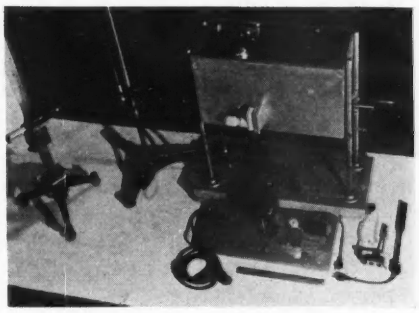

FIG. 2. Details of constant temperature bath.

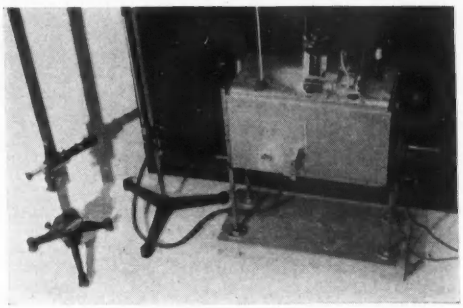

FIG. 3. Assembled apparatus.

The current for the 500-w heater is controlled directly by a Cenco-De Khotinsky (d.p.s.t.) regulator. Two 0.25-μf condensers are connected across the regulator contacts. A pilot lamp indicates when the heating current is on. Fig. 3 shows these parts assembled on the cover of the tank. Both the motor and the thermoregulator are mounted on sponge rubber pads to prevent sparking at the control contacts due to vibration. This apparatus has been used satisfactorily in the range from 0° to 60°C.

Two diameters of Corning thermometer tubing, both about 30 cm long, have been used. For a capillary bore of radius 0.015 cm, air will flow for about 160 sec, when the difference in level of the mercury columns is about 20 cm. For a bore of radius 0.022 cm the time is about 35 sec. The accuracy of the coefficients of viscosity measured with the smaller capillary is within 2 percent, becoming less accurate for larger tubes.

The Progressive Exhibit Method

A New Technic in the Field of Science Presentation

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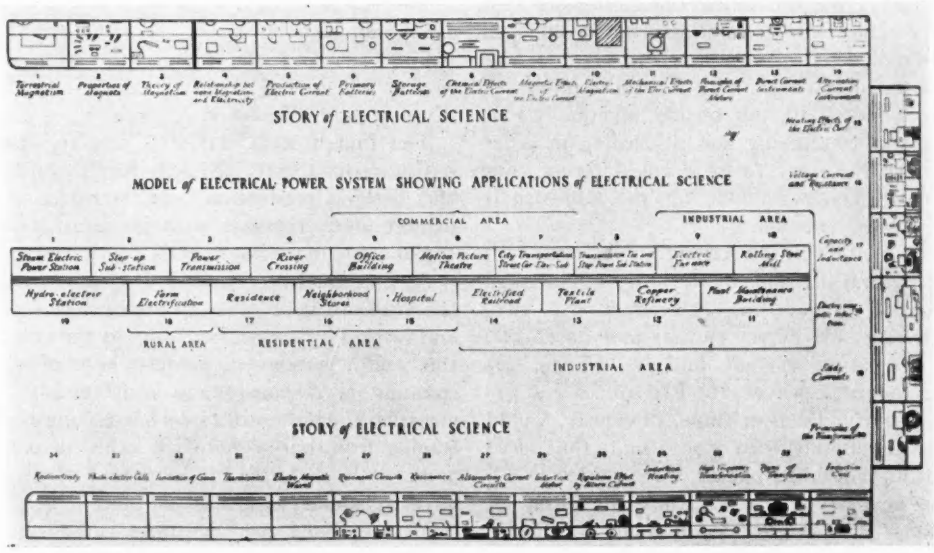
Director, New York Museum of Science and Industry, New York, New York

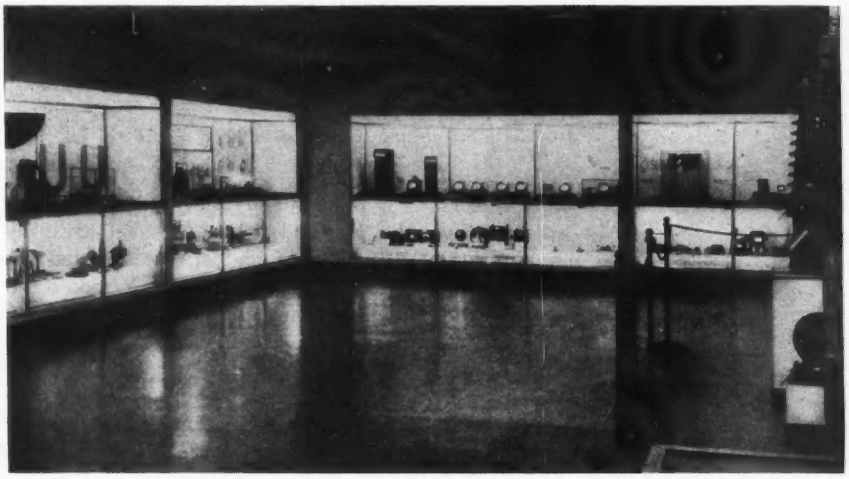
THOSE who seek to present scientific subjects to the layman so that he will readily understand their basic principles, and appreciate their true significance in his own everyday life, must be continually searching for better and more effective ways of making this presentation. Here at the New York Museum of Science and Industry, where over half a million people from all over the world come under our observation every year, a method of scientific exhibition has been devised to give the visitor, in a few hours, a logical and coordinated knowledge which would take him many months to get from books or through any other educational medium. Moreover, the exhibit is worked out in so novel a fashion that even those who approach it with only the mildest curiosity about the sciences soon find this casual curiosity turning into real interest.

The idea underlying the method is to arrange the material so as to take advantage of the visitor's motive instinct—his natural urge to see or to set things in motion—and also to intrigue him into reading descriptive material, a thing he usually sidesteps if possible. Thus he acquires an initial understanding of basic scientific principles by personal participation in demonstrations so fascinating that he is lured into reading accompanying printed data to further this understanding.

We call this our Progressive Exhibit Method of Presentation. It offers the visitor the outstanding discoveries and developments of a particular branch of science, together with their important applications, in connected story form. The Electrotechnology Division in the New York Museum of Science and Industry offers an excellent example of the use of the method.



The story of electrical science and its applications as worked out by the Progressive Exhibit Method. Limitations of space have as yet permitted only a partial presentation of this completely organized program; but from this working diagram it is possible to adapt the plan, as the Museum itself has done, to given conditions of space.



A corner of the Electrotechnology Division.

The first step in planning our presentation of the story of electricity by the Progressive Exhibit Method was to write a script, setting down the most significant and important ideas that we proposed to translate into exhibit form. The preparation of such a script for a science exhibition was much like preparing a scenario for a play, the difference being that we cast science exhibits, instead of men and women, in the role of actors. Assembling our material was a matter involving, first, a vast amount of research and study, and, second, an equally vast amount of condensing and discarding in order to reduce the story to its simplest terms, thus making it understandable for the audience it was designed to reach.

In its final form, the script resolved itself into seven natural divisions of the story of electrical science: (1) Magnetism, (2) Production of electric current, (3) Direct current and its effects, (4) Alternating current and its effects, (5) Electromagnetic waves, (6) Electronics and (7) Radioactivity. Each of these, obviously, would require subdividing into exhibit units that serve to explain individual phases of the subject.

Our next step was to study all forms of mediums that might be used to dramatize clearly and effectively every one of these main divisions of our story. The list finally selected included: moving models operated automatically; moving models operated by the visitor; static models; dioramas, motion pictures, balopticons, diagrams, sketches and legends.

The third step was to reduce the exhibition to an actual plan on paper that would take into consideration specified limitations of floor space and expense. In this stage, such things as architectural design, illumination, color treatment and distribution of the most spectacular exhibits entered the picture, as well as the matter of routing visitor traffic through the division most efficiently.

The fourth and final step was to cast the entire project into physical form, comprising the design, production and housings of the exhibit units, together with preparation of the explanatory material, legends and lettering.

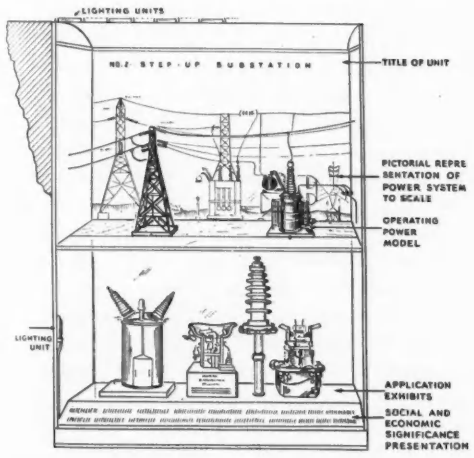
As our Electrotechnology Division stands at the moment, it presents an appearance of lively and intriguing action. Standing in the entrance, the visitor catches a glimpse here of a ring spinning mysteriously and continuously on a glass plate, and there of a steel band spontaneously leaping from one side to the other of a metal arch, both without any apparent motivating force. A sudden blue flash of electricity, like a small streak of jagged lightning, catches his eye in one corner, while almost immediately his attention is arrested by a crackle and buzz from another direction. Drawn irresistibly inside to

investigate these diverting phenomena, he finds himself surrounded by objects either moving miraculously by themselves or waiting for the pressure of his finger on a button to spring into dynamic action.

At this point, something usually happens to that mild curiosity with which our visitor paused at the doorway. He wants to find out what makes that ring spin; what caused that blue flash; where that spitting noise is coming from and why; and what would happen if he should walk over and press that button.

Presently, as he looks around, he begins to see that there is a starting place in all this, and in a moment more, he becomes aware of order and organization. He sees that this room is arranged in a series of exhibit units, each unit corresponding in design with its fellows on either side, and that the proper way in which to get an idea of what it is all about is to begin at the first unit and follow along one after the other, studying each as he would a chapter in a book. And with that, he plunges, fascinated, into unit, or chapter, number one, dealing with Terrestrial Magnetism.

In this unit, as in each of the 29 others which, in our present setup, carries the story of electrical science through the first four of its seven main divisions, the fundamental ideas and experiments are shown by operating exhibits on a working level, convenient to the visitor's hand, with explanatory material on the wall in the background at eye level. Historical exhibits applying directly to these operating exhibits are shown in a case below, with a short and carefully worded summary at the bottom which leads into the subject matter of the unit immediately following, serving as a connecting thread binding all together.



Plan of Unit, or Chapter, 11 in the story of electrical science. It explains how the exhibit material in an individual unit is organized by the Progressive Exhibit Method.

In passing, it might be interesting to state that these summaries taken alone could stand by themselves as a clear and concise story of electricity, even if all the exhibit material were eliminated. Indeed, the same could be said of any of the other parts of each unit, if followed throughout the entire series. That is, all the explanatory material in the background would, as now arranged, present by itself a connected narrative of electrical science, as would all the operating exhibits, taken successively, and all the historical exhibits. For, to our way of thinking, a test of the success of any display worked out by the Progressive Exhibit Method would lie in the ability of each corresponding section, whether background material, operating devices, historical exhibits or worded summaries, to present by itself, a complete running story, independent of all the others.

Some of the exhibits in the terrestrial magnetism unit are automatically operated and some are visitor-operated. Here, by means of a large section of a globe with a needle continually revolving around it, the visitor is made aware that the earth is a magnet with magnetic lines of force reaching from it. Here, too, is an earth inductor which he can operate himself, rotating a loop of wire which generates a current of electricity in the earth's magnetic field, shown together with small pieces of lodestone acting as compasses. Natural developments from these to the compass of today are shown.

The second unit in the story deals with the properties of magnets; and the visitor is given an added glimpse of the magnetic field, so important in the story of electricity, by means of an exhibit called "Iron Fur." This demonstration consists of a mass of iron particles which assume fur-like forms between revolving lodestones. The familiar artificial magnet is here, too, and its properties of attraction and repulsion

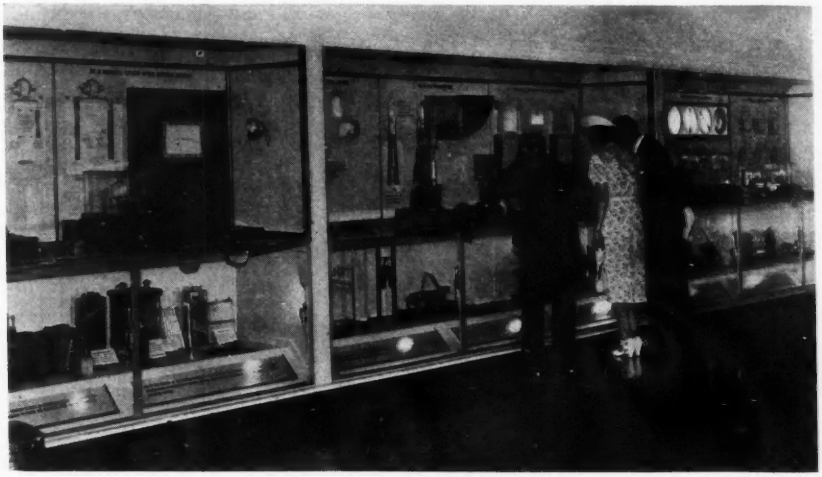
are demonstrated by some rather striking magnetic combinations which go through a variety of motions. In the background, a large transparency of the magnetic fields of such magnets shows the reasons for these forces of attraction and repulsion.

The third unit comprises one automatically operating exhibit and one that the visitor can operate himself. Together they seek to make clear just what magnetism is, or, in other words, to demonstrate the theory of magnetism. The former, operating continuously, subjects an iron bar, first, to direct-current magnetization and, then, to alternating-current demagnetization, the effects of these changes being seen by the iron bar's attraction and repulsion of suspended iron balls between which it passes. The visitor-operated exhibit demonstrates the Barkhausen effect, in which the visitor magnetizes and demagnetizes hard and soft steel samples and actually hears the sound of the effect of the magnetic particles moving in the material as they line up and scatter, noting the difference in sound between the action of the two samples. All of the foregoing unit exhibits are grouped under the first of the seven main divisions of our Story of Electricity; namely, the subject of magnetism.

Children operating alternate- and direct-current generators by means of push buttons and handles

Coming to the second main division—the Production of Electric Current—we have four units dealing, respectively, with (1) a demonstration of the classical Faraday experiment, in which Faraday took a bar magnet and, in moving it quickly in and out of a coiled wire, produced for the first time electric current by mechanical means; (2) generators, in which, by pressing buttons and turning handles, visitors may actually generate electric current and see it register itself on wall meters, together with material which explains the difference between alternating and direct current; (3) primary batteries, where the visitor again operates the demonstration himself, and (4) storage batteries, with a visitor-operated mechanism by which the turn of a knob will charge and discharge a battery. On the background in the unit on the primary battery, the visitor is given, by means of a moving representation of Galvani's classical frog legs experiment, a graphic appreciation of what the primary battery is and how it was discovered.

Now, having shown our visitor how electric current is produced, we next undertake to demonstrate to him—through his eyes and, wherever practical, by letting him use his hands—the effects of direct current. First, we show him its chemical effects, letting him press buttons to give himself a demonstration of the electrolysis of water and another of electroplating. This latter demonstration is one of the most popular in the Electrotechnology division. It permits the visitor to immerse a small plate in a copper sulfate bath and bring it up copper-coated; then to immerse it again and remove the coating by reversing the current. In three succeeding units, the magnetic effects of electric current, electromagnetism and the mechanical effects of electric current are demonstrated. The first is demonstrated by an automatically operating reproduction of Oersted's experiment showing the magnetic field and its direction about a wire carrying current; the second, by push-button devices, one demonstrating the pulling power of a solenoid and the



Visitors operating the apparatus that shows the mechanical effects of the electric current.

other, the field of an electromagnet; while in the third the visitor uses push button and knob to show the movement of a wire carrying current in a magnetic field, which is the fundamental principle of the direct-current motor.

To focus the story more sharply for the visitor, such common and useful devices for applying electricity as the electric motor and electric meters are next shown. The working principles of these are explained on the background, according to the usual treatment, with operating exhibits conveniently located in the foreground and historical material below in the uniform cases. The operating exhibits in this unit consist, first, of Faraday's motor, which the visitor operates by a push button to set a wire continuously rotating around a center pole magnet, and second, two other visitor-operated motors of later design that demonstrate the basic principles under which modern motors operate.

Two succeeding units present, respectively, direct- and alternating-current voltmeters, operable by push buttons; and then the visitor comes to the unit demonstrating the heating effects of electric current. The main feature here is a pyrometer, with a push button which sets the heating unit glowing while its increasing temperature registers on a meter. In a second piece of apparatus the visitor pushes a button to observe the I^2R effect. The ordinary electric lamp and many household and industrial appliances which depend upon the heating effect are included in this group of exhibits.

The next two units concern themselves with studies of voltage, current and resistance, as well as capacitance and inductance; and in these, again, the visitor pushes buttons, throws switches and turns handles to give himself action-demonstrations of the basic principles involved.

The importance and significance of the phenomena of electromagnetic induction, upon which rests the entire electrical science and industry, is next shown in a simple operating device, the conception for which was derived from an exhibit made by a child and shown at a science fair. It consists of two horseshoe magnets on which two coils of wire in the form of pendulums can be moved, and in itself tells practically the whole story of electricity.

A unit on eddy currents, demonstrated by a visitor-operated device, is next. It precedes a study of the principles of the transformer, with which begins the story of alternating current and its effects. By pressing a button and turning a knob, the visitor operates an exhibit that shows him the fundamental principles of the transformer, and from there he passes on to three other units in which the induction coil, the high voltage transformer and the high frequency transformer are presented in dramatic demonstrations which operate on automatic time sequences.

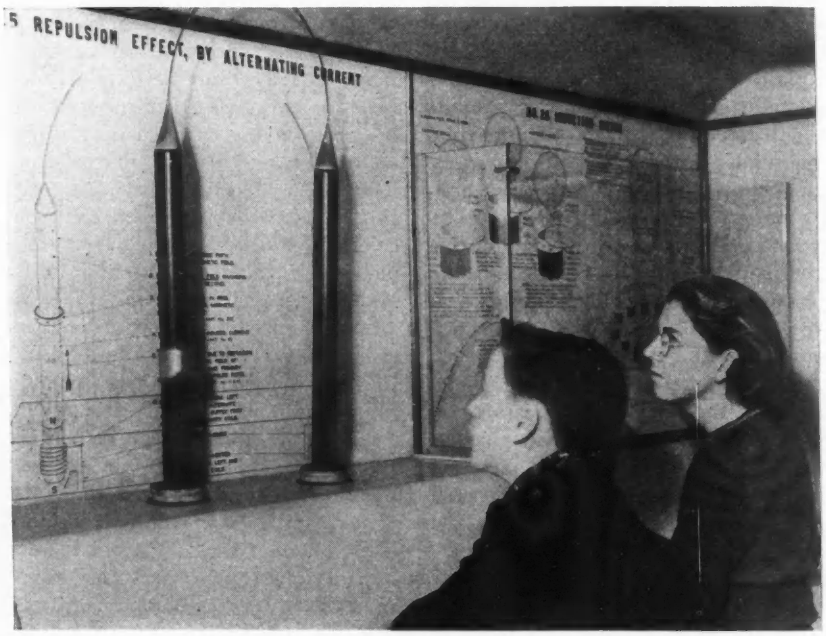
Following these, there are units in which the visitor again is permitted to be his own showman in operating, by push buttons, devices that demonstrate inductive heating, the repulsion effect and the induction motor. In the first of the three, a system of moving levers causes a match to be put into an induction furnace and come out unlit; following this, a metal ring goes in and emerges red-hot. This vividly demonstrates that, although there is apparently no heat in this furnace, it can be used to melt steel.

The device used to illustrate the repulsion effect, we call the Jumping Ring. In this, a metal ring of some size is repelled, when a button is pressed, up one guide and down another, alternately back and forth, without any apparent motive force. Visitors stand fascinated for long periods in front of this mysterious performance, as well as before the next, and equally mysterious, demonstration consisting of one action-exhibit operated by a push button and one automatically operated. The push button sets a large copper ball spinning in a glass container full of liquid, while the second exhibit shows a ring spinning dizzily and continuously on a glass plate. We have found that such entertaining and puzzling exhibits as these stimulate, almost without exception, the observer's curiosity to a point where he carefully studies the explanatory material in the background to find out what makes these things go through their unaccountable motions. In thus satisfying his curiosity, he has, at the same time, painlessly discovered for himself important scientific principles.

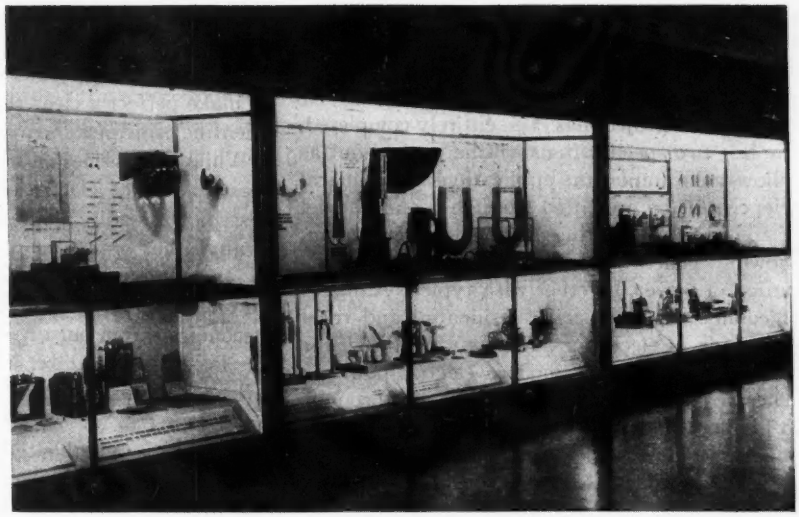
By this time the visitor usually has become sufficiently interested to do a little thinking for himself; so in the next unit we have the hardihood to suggest that he do this by actually propounding a question on the legend of one of the devices he can operate. The instructions read:

> Turn knob at the right to Direct Current. Then press button and add the readings of the first two voltmeters, which should equal the reading of the one at the right. Now turn knob at the right to Alternating Current and press button. Note that the sum of the readings of the first two meters is now greater than the reading of the third. Why?

True, the answer is ready at hand, so as not to leave him entirely to his own devices; but the chances are that he will at least make a stab at



The Jumping Ring exhibit, in which the metal ring leaps from one side to the other of the arch in a demonstration of the repulsion effect of alternating current.



On the working level, convenient to the visitor's hand, are seen the operating exhibits demonstrating fundamental principles, experiments, discoveries, etc., with explanatory data on the wall in the background and historical material in the cases below, together with brief summaries which tie the exhibit together in a running story.

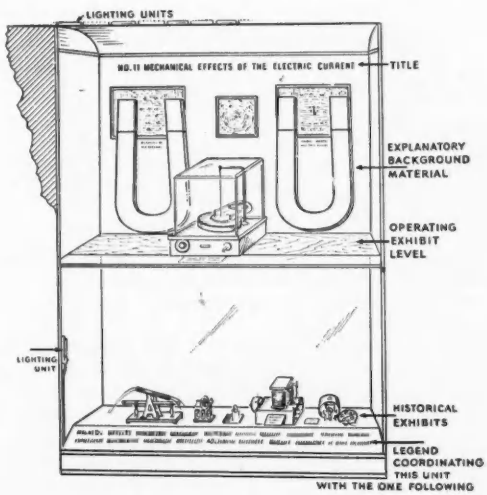
finding out for himself first. And in any event, he learns something which will further his understanding in regard to direct and alternating current, even though he may not remember to specify resistance, inductance and capacitance in telling about it afterward.

Then, concluding the subject of alternating current and its effects, we present, in two last units, one operating automatically and the other visitor-operated, the fundamental conception of resonance and resonant circuits.

This completes the story of electricity as far as we have taken it, to date, in the Electrotechnology division of the New York Museum of Science and Industry. The visitor is led progressively, step by step, through a series of animated demonstrations that show him graphically the principles of magnetism, how electric current is produced, what direct and alternate currents are and the effects of each. Supplementing every exhibit, as we have already pointed out in general though not reiterating in each instance, is explanatory and historical material that makes each unit a rounded-out and complete chapter of a connected story.

When our entire project is completed, it will treat, in form similar to that just described, electromagnetic waves, electronics—subdivided into thermionics, ionization of gases and photo-electric cells and their applications—and radio-activity.

Our theory is that a properly organized science exhibit should bring out four main points: (1) the scientific principle or development involved, (2) its scientific historical background, (3) the more important applications of the principle and (4) the social and economic significance of the development. As far as our Electrotechnology Division has gone, up to the present time, in



Plan of an individual unit in that part of the story of electrical science which deals with its applications, together with its social and economic significance. The position of this unit and others in the same category may be seen by a glance at the center part of the diagram showing the entire organization scheme.

presenting the story of electrical science by the Progressive Exhibit Method, we have fulfilled the first two specifications of this formula and part of the third.

When the project has been entirely completed, the last two specifications will be worked out as follows: the important applications of electrical science will be presented through a scale model of an actually operating electrical power system, showing generation, transmission and distribution of power, together with typical examples of commercial, industrial, residential and rural utilization of electricity. In this way the visitor will see not only how modern electric power is generated at the source but also how it is brought to his door and the part it plays in motivating important factors of his everyday life. In the background behind this setup, an elaborate mural diagram will picture a complete power system to scale, showing all of the significant pieces of electrical apparatus and equipment. Furthermore, the whole project will be so coordinated as to make perfectly clear the relationship between scientific principles and applications of electricity.

While this discussion has been confined to the presentation of electrotechnology, the method described is readily applicable to the presentation of any other branch of pure or applied physics. It is ideally suited, for instance, to the presentation of light and optics, sound, heat and mechanics. From our experience here, we believe this Progressive Exhibit Method of Presentation to be a technic by which scientific subjects can be interpreted for the layman in logical and clearly understandable terms. It is our hope that this outline of it will be helpful to others who may be confronted with similar problems.

Some Experiments on the Teaching Value of Sound Films in College Physics

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THE educational psychologist has long recognized the value of bringing to bear upon any given problem in learning as many of the sense perceptions as possible. The college physics teachers are now dealing with talking motion pictures as a technic in the teaching of their materials. The principal advantages seem to be:

(1) Demonstration experiments presented by means of motion pictures never fail and can be repeated as often as desired.

(2) The apparatus needs to be set up only once.

(3) The demonstration can be perfectly made, down to the slightest detail.

(4) The oral description can be given in exact language without slip or an omission.

(5) The number of experimental demonstrations that can be completed in a class period appears to be double or triple the number possible with actual demonstrations.

(6) Every student is assured a clear view of the demonstration.

(7) The use of animated drawings makes possible the clear demonstration of swift, complicated or otherwise invisible action, with a large gain in understanding by the student.

(8) Experimental demonstrations can be made that, for a variety of reasons, are barred from the lecture table.

(9) The method is more economical.

The disadvantages appear to be:

(1) The action is very swift and logical, and a student may easily miss a key point or points, without which the demonstration is unintelligible.

(2) Many of the personal and human contacts of actual demonstration are missing.

(3) The student does not have a good opportunity to take notes.

(4) Questions cannot be directed to, or answered by, the picture.

Some of the disadvantages can be neutralized by showing the picture two or three times, by discussion and comments by an instructor before or between the showings, and by distributing to the students a printed copy of the spoken words.

First Study

Two studies are here reported. The first study was made with the Erpi sound film, "Molecular Theory of Matter," to determine, if possible, what value it had when used as a review over material that had already been covered by the regular class and laboratory work.

The talking film was run twice before Section *A*; between the two showings comments were made by the instructor on certain parts of the film to be observed during the second showing. Section *B* did not see the film. Three days later both sections were given a semester final examination in the course. This examination consisted of four parts: *Cooperative Physics Tests for College Students: Mechanics, Heat, and Sound*, 90 items; and a multiple choice test on molecular theory, 13 items. Thus a total of 103 multiple choice items constituted the entire examination. Before the Cooperative tests were given, they were carefully scrutinized for items, the answering of which might be affected by seeing the film. Twenty-nine such items were found. They were divided into three classes: 10 items the answers to which might be obtained directly from the film; 6 items that were covered by the film in a less direct way; and 13 items the answers to which were more or less remotely suggested by the film.

Forty students in Section *A* who saw the film made an average net score of 29.43 on the 74 items in the first three sections of the final examination that had nothing to do with the material covered in the film. On the same items, 36 students in Section *B* who did not see the film made an average net score of 35.6. The ratio of the scores of *B* to *A* is 1.21. It is of interest to note that the ability-ratio of the two sections on 200 objective items of the same type divided into four mid-semester examinations was 1.23.

On the 16 examination items bearing most directly on the material covered in the film, Section *A* made a net score of 7.84. If it be assumed that the average difficulty of these items is the same as that of the 74 mentioned previously, and if the mid-semester ratio, 1.23, is taken as the more reliable of the two ability-ratios, the expected score is 6.92. The difference between these scores divided by the standard error of the difference gives 2.39, which means that the chances are 94 out of 100 that this result is significant.

If the same type of computation is made for the entire 29 items that were selected from the test as having bearing on the picture, the difference between the scores divided by the standard error of the difference is 4.4, which means that the result is certainly significant. The sound film, "Molecular Theory of Matter," *is an effective review agency as measured by examination items of the type found in the Cooperative Physics Tests for College Students.*

Second Study

The Erpi sound film, "Electrostatics," was shown twice to 54 students in Section *A*. During the intermission the instructor commented on the picture and urged that attention be given to certain details during the second showing. The following hour a carefully prepared 50-min demonstration lecture was given to Section *B*. It covered very nearly the same material as the film, and used almost identical equipment and experiments. The lecture was carefully prepared and class members declared it to be quite superior to the regular performance of the same lecturer. Both sections were asked to read Stewart's *Physics* (rev. ed.), paragraphs 383–397; this covered part of the material demonstrated by the film.

During the following class hour a test of 26 multiple choice items covering the material in the film and the lecture was given to both sections. With the score of Section *B* taken as standard, the predicted score of Section *A* was 12.82 while the actual score was 14.2. The statistical evidence is not conclusive, but *it is highly probable that the sound film was more effective than the lecture in teaching the material covered by the 26 test items.*

After the test, a demonstration lecture was given to Section *A* in which the material covered by the film was reviewed and amplified. A lesson was assigned in Stewart's *Physics*, paragraphs 397–405, which included six problems, mostly on Coulomb's law. At the next meeting of the class the same test was again given to Section *A*, and it scored an average of 16.7, a gain of 2.5 points or about 18 percent. It is impossible to say that this gain was due to any one thing. It is noteworthy, however, that the standard deviation for the two scores for Section *A* were 4.3 and 3.72, respectively. This indicates a decided gain for the low members of the class. These findings at the college level are quite in line with the reported findings among grade school children.[1]

[1] E. Dale and L. Ramseyer, *Teaching with Motion Pictures* (Am. Council on Educ., Apr., 1937).

A Discussion of Bertrand's Problem

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BERTRAND'S[1,2] problem may be stated in the following way: In a circle a chord is drawn. What is the probability that the length of the chord will be greater than that of a given chord? As the problem was proposed to the present writer, the given chord was taken as a side of an equilateral triangle inscribed in the circle. Three solutions were offered to him; they may be briefly stated as follows.

(1) Imagine a radius vector drawn at right angles to any chord. Then, in order for the chord to be longer than a side of an inscribed equilateral triangle, the point of intersection of chord and radius vector must lie between the center of the circle and a point on the radius vector midway between the center and the circumference, as is obvious from Fig. 1(*a*). The probability from these considerations is, of course, $\frac{1}{2}$.

(2) Take any chord of the circle and inscribe in the circle an equilateral triangle with vertex at one end of the chord. Consider the angle that the chord makes with the straight line drawn tangent to the circle at this vertex. All possible values of this angle range from 0 to π, while the values that will satisfy the condition of the problem include those between $\pi/3$ and $2\pi/3$. Hence the probability of satisfying this condition is $\frac{1}{3}$.

(3) Take any chord and consider its midpoint. In order that the chord be longer than the given chord, the midpoint must lie inside a circle concentric with the given circle and having a radius equal to one-half that of the given circle. We see that the area of the smaller circle is $\frac{1}{4}$ the area of the given circle; so the probability that the midpoint will lie inside the smaller circle is $\frac{1}{4}$.

Here we have three different solutions with as many different answers. Now let us consider two solutions offered by D. J. Struik[3] which are somewhat analogous to solutions (1) and (2). Introduce the angle θ [Fig. 1(*b*)] which the radius OQ makes with a fixed direction, and the distance $OH=s$ from the center O to the chord. All possible positions of the chord PQ are obtained by letting θ vary from 0 to 2π and letting s vary from 0 to a, where a is the radius of the circle. All favorable positions are obtained by allowing θ to vary from 0 to 2π, and s from 0 to $a/2$. The probability is then given by

$$P=\int_0^{a/2} ds \int_0^{2\pi} d\theta \Big/ \int_0^{a} ds \int_0^{2\pi} d\theta = \tfrac{1}{2}.$$

Now take the variables θ and φ. All possible positions are obtained by varying θ from 0 to 2π, and φ from 0 to $\pi/2$. The interesting cases are

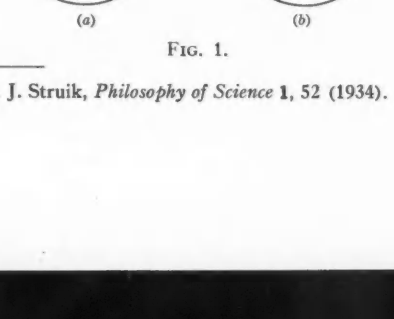

FIG. 1.

[1] J. L. F. Bertrand, *Calcul des probabilités* (Gauthier-Villars, 1889), pp. 4–5.

[2] This paper, which the undersigned writer had the pleasure of reading in manuscript, is of particular interest to physicists, since it emphasizes, by discussion of a special example, that there is no such thing as an *a priori* solution of a probability problem fully determined by the formal theory of probability. The classical theory of probability merely provides us with rules for calculation of relative frequencies of events when the physical conditions of the problem provide us with a reasonable hypothesis as to what are the elementary "equally likely" cases in the situation. I have often sought to give point to this fact by emphasizing that no one has ever given even a first approximation to the problem of the noncubical die. In its simplest form this problem may be put as follows: Suppose a rectangular die is cut from a block of homogeneous material with edges 1, 1 and $1+x$, where x may have any value from -1 to ∞. It is put in a leather cup whose internal dimensions are large compared to the size of the die, shaken and thrown a large number of times from a distance large compared to the size of the die onto a green felt cloth stretched tightly over a smooth horizontal table. In what fraction of the throws will one of the two square faces be horizontal, in contact with the table top? Reflection on this problem will show how strongly we rely on the symmetry argument for $x=0$ and how little we know how even to get started on the question when $x\neq 0$. Readers who are interested in the point of view presented in this paper will enjoy reading Lecture II, on "Probability and Experimentation," by J. Neyman, in *Lectures and Conferences on Mathematical Statistics* (Graduate School, U. S. Department of Agriculture, Washington, D. C., 1938).—E. U. Condon.

[3] D. J. Struik, *Philosophy of Science* **1**, 52 (1934).

obtained if we let θ run from 0 to 2π and φ from 0 to $\pi/6$, and the probability is given by

$$P=\int_0^{\pi/6}d\varphi\int_0^{2\pi}d\theta\Big/\int_0^{\pi/2}d\varphi\int_0^{2\pi}d\theta=\tfrac{1}{3}.$$

According to Struik both these answers are formally correct. We can say precisely the same thing for the first three solutions given. Struik points out that the difficulty arises in defining "equally likely" cases. In obtaining the foregoing solutions the "equally likely" cases have been defined in different ways; and in the formal theory of probability all these ways are possibly, although, of course, not simultaneously, correct. That is, from the statement of the problem, there does not seem to be any obvious reason why we should choose one set of variables in preference to another. This ambiguity becomes very apparent with the following considerations. Let us refer again to solution (1). There we considered the midpoint H [Fig. 1(a)] of any chord PQ and said that the favorable cases were those for which H was on the segment OL of the radius vector OT. These considerations gave us a probability of $\frac{1}{2}$. There is nothing in the statement of the problem, however, to prevent us from considering the point Q instead of the point H. In order that the chord PQ be greater than the given chord, Q must lie on the arc NS, while in general it may lie anywhere on TS. The probability then will be the ratio of NS divided by TS, which is $\frac{1}{3}$.

Despite the varied answers which have been obtained, one feels certain that, if an experiment were conducted under fixed conditions in which a straight wire was dropped at random upon a plane containing a circle, the quantity n/N, obtained by dividing the number of times n the wire intersected the circle to form a chord longer than a given chord by the total number of times N the wire intersected the circle in two points, would approach a definite quantity as the number of trials became very large. Let us try to see where the error enters in comparing the problem as previously stated to the physical experiment just described.

The problem was stated: "In a circle a chord is drawn. What is the probability that the length of the chord will be greater than that of a given chord?" We immediately recognize the fact that, in specifying in the experiment that the wire fall at random on the plane, the "equally likely" cases have been determined, while in the statement of the mathematical problem all that is said is that "a chord is drawn," and nothing is said as to how it shall be drawn. The problem now is to determine what is meant by a random chord or line.[4] Let us consider three different ways of drawing a chord in a circle:

(A) Two random points on the circumference of a circle are joined by a straight line.

(B) A point is chosen at random in a circle and a chord is drawn through the point normal to a radius vector through that point.

(C) A line is drawn at random across a circle.

In (A) the distribution of lines or chords is through random points; but since, for a given direction, such lines lie closer together near the circumference than they do near the center, they are not random lines.

In (B) the distribution of chords is through random points and again undue weight is given to lines near the circumference, since we may consider the lines as tangents to a series of concentric circles drawn with their centers at O, Fig. 1(a). Because the radius of C' is one-half the radius of C, the same number of circles may be drawn within C' as between C' and C, but the circumference of the smallest circle between C' and C is greater than that of the largest inside C'.

There may be a question as to whether or not a random chord is the same thing as a random line.[4] We shall here consider the two as equivalent.

We have, then, given three methods of drawing a chord in a circle, any one of which might fulfill the conditions of the problem, but each one gives a different type of distribution and hence defines different "equally likely" cases. Method (C) seems to fit solution (1) and the first solution presented by Struik. Method (A) corresponds to solution (2) and Struik's second solution. Method (B) corresponds to solution (3). The results obtained in solutions (2) and (3) seem to indicate that more weight was given to chords near the circumference than was given in solution (1) since both are less than $\frac{1}{2}$.

[4] For a discussion of random chords see "Mathematical Questions with Their Solutions," Educational Times **29**, pp. 17–20 (1878).

Now which one of these methods of drawing a chord with its corresponding solution gives us conditions analogous to the random fall of a wire on a plane? Morgan Crofton[5] defines a random line or chord in a manner similar to the following statement: Imagine infinitely many lines drawn in all possible ways on a plane; a random chord will be determined by choosing at random any one of these lines that crosses the circle under consideration. It seems that this definition fits the conditions of our experiment as well as those of method (C) and solution (1); even so, we cannot be sure until the physical experiment is performed.

In applying the formal theory of probability to a physical situation, this question as to which are the "equally likely" cases always arises. In some instances it may be easily answered, but usually a definite answer can be determined only by experiment. One might wonder just why we are ever justified in applying the formal theory of probability, with its necessary "equally likely" cases, to a physical situation. It is usually found that a function which expresses the probability of occurrence of any one of a set of events has a maximum near one or more of the set; and so we are perhaps justified in assuming that, in the region of this maximum, the probability function is a constant. As an example, in the case of the particular problem under consideration, suppose a person stood on a large plane and tossed a stick in the direction of a given point in front of him on the plane in an attempt to hit the point. If we assume that he stands at the origin of coordinates facing the positive x-direction, and that the point is, say, 10 ft in front of him, the probability that the stick comes to rest at a distance of 100 ft in front of him, or behind him, will be very small. If we let $P(x)$ represent the probability that the center of the stick will have a given x-coordinate when it comes to rest on the plane, then the function $P(x)$ will have a maximum near $x=10$ ft, and the graph of the function might be similar to that in Fig. 2. The probability function of the

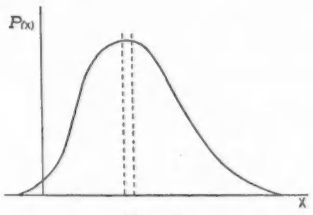

FIG. 2.

y-coordinate would be somewhat similar and so, within a radius of, say, 1 ft from the point aimed at, we might assume the probability function to be a constant. This assumption is at best, however, an approximation. It must be remembered that this probability function (and likewise the function expressing the probability of a given direction of the stick) depends upon the way in which the stick is thrown. The present problem is not different from any other in this respect. For example, given a die, one cannot be sure that the probability of throwing 1 is the same as the probability of throwing 6; the die might be loaded. The only way to find out is to make the experiment.

Experiment indicates that when a stick is "tossed at" a circle in a manner similar to that just described, Bertrand's problem has an empirical answer near $\frac{1}{2}$.

The author wishes to express his appreciation to Professor Carl Eckart, whose aid and encouragement were indispensable in completing this paper, and to Dr. Philip Fox, through whom the problem was brought to the author's attention.

[5] Article "Probability," *Encyclopædia Britannica* (ed. 9), par. 75.

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REPRINTS of the following survey articles which have appeared in various issues of *The American Physics Teacher* may be obtained at cost from the Editor, Pupin Physics Laboratories, Columbia University, New York, New York. Stamps will be accepted in payment.

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The Frequency Produced by the Combination of Two Vibrations of Nearly Equal Frequency

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WHEN a vibration represented by $y_1 = A \sin pt$ is combined with another in the same straight line, $y_2 = a \sin (qt+\delta)$, the resulting vibration, $y = A \sin pt + a \sin (qt+\delta)$, is in general not simple harmonic. In the special case when the frequencies of the component vibrations are nearly equal, giving the phenomenon of beats, it is possible to express the resulting vibration analytically in a form closely analogous to that used for harmonic motion and to draw certain conclusions from the result. Many textbooks on sound have pursued the analogy too far and have reached inexact conclusions.

Let p be slightly larger than q so that $p-q$ is a small quantity compared to p or q. The equation for the resultant vibration may be written,

$$y = A \sin pt + a \sin [pt-(p-q)t+\delta],$$

and this may be put in the form

$$y = C \sin (pt-\Delta),$$

where

$$C^2 = A^2 + a^2 + 2Aa \cos [(p-q)t-\delta]$$

and $$\tan \Delta = \frac{a \sin [(p-q)t-\delta]}{A + a \cos [(p-q)t-\delta]}.$$

The conclusions drawn from the foregoing analysis are often unnecessarily inexact. For example,

> Thus the resultant vibration represents a vibration of the same period as the larger force $A \sin pt$ with fluctuating amplitude reaching a maximum equal to the sum of the component amplitudes, with a frequency equal to the difference $(p/2\pi)-(q/2\pi)$ of the component vibrations; and phase lag from 0 to a/A (fractions of 2π) behind the larger force.[1]

This statement is inconsistent in itself; the resultant cannot be of the same frequency as the larger force and at the same time have a varying phase lag with it. Moreover, a slightly different mathematical treatment will result in

$$y = C \sin (qt+\beta)$$

in which the resultant seems to have the same frequency as the smaller force. In general, the resultant does not have a definite frequency: its frequency varies with time; it fluctuates. All that can be said[2] about the resulting frequency from the expression $y = C \sin (pt-\Delta)$ is that, if Δ does not vary much during one vibration, the frequency is approximately $p/2\pi$, which is also approximately the same as $q/2\pi$.

The frequency during beats fluctuates or warbles. It is a function not only of the frequency constants p and q but also of the time t and of the amplitudes A and a. Let us consider three special cases in which the approximate frequency can be readily found:

Case 1. *The frequency when the amplitude of the beats is near its maximum.* Let

$$(pt_1-\Delta_1) = 2n\pi$$

and $$(pt_2-\Delta_2) = 2(n+1)\pi.$$

The time t_2-t_1 will then be the period of the vibration. When the amplitude is a maximum,

$$\cos [(p-q)t-\delta] = 1.$$

At times near this, $[(p-q)t-\delta]$ may be written as $2m\pi+\theta$, where θ is a small angle. Then

$$\tan \Delta = \frac{a \sin (2m\pi+\theta)}{A + a \cos (2m\pi+\theta)} \doteq \frac{a\theta}{A+a} \doteq \Delta.$$

For small values of θ, $\sin (2m\pi+\theta) \doteq \theta$ and $\cos (2m\pi+\theta) \doteq 1$; and, since θ is small, $\tan \Delta$ is small and may be taken equal to Δ. Since

$$\theta = [(p-q)t-\delta]-2m\pi,$$

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[1] E. G. Richardson, *Sound*, second edition (Edward Arnold, 1935), p. 60.

[2] H. von Helmholtz, *Sensations of Tone*, second edition (Longmans, 1885), Appendix 14, p. 414.

$$pt_1-\Delta_1=pt_1-\left(\frac{a}{A+a}\right)[(p-q)t_1-\delta-2m\pi]$$
$$=2n\pi,$$
$$pt_2-\Delta_2=pt_2-\left(\frac{a}{A+a}\right)[(p-q)t_2-\delta-2m\pi]$$
$$=2(n+1)\pi,$$
$$p(t_2-t_1)-\left(\frac{a}{A+a}\right)[(p-q)(t_2-t_1)]=2\pi.$$

Therefore,

$$t_2-t_1=2\pi(A+a)/(pA+qa),$$

and the frequency is $f_1=(pA+qa)/2\pi(A+a)$, which is a weighted mean of the component frequencies, weighted in proportion to the amplitudes. When the amplitudes are equal, this becomes the arithmetic mean of the component frequencies.

Case 2. *The frequency when the amplitude is near its minimum, for cases where A is appreciably greater or less than a.* Near the minimum amplitude of the vibration, $\cos[(p-q)t-\delta]$ is approximately -1. An exactly similar analysis will yield the frequency in this case as $f_2=(pA-qa)/2\pi(A-a)$, but it will be necessary to make the additional condition that $A-a$ is not a very small quantity. We cannot check it against the case where the amplitudes are equal.

An example will show an interesting aspect of these solutions; namely, while at the maximum the frequency is between that of the two components, at the minimum it may be higher (or lower), by a significant amount, than either component. Let $A=2a$. For maximum amplitude the frequency is

$$f_1=(2p+q)a/2\pi\cdot 3a=(2p+q)/2\pi\cdot 3$$
$$=[3p-(p-q)]/2\pi\cdot 3=[p-\tfrac{1}{3}(p-q)]/2\pi,$$

which is between that of the two components. For minimum amplitude the frequency is

$$f_2=(2p-q)a/2\pi(2a-a)=(2p-q)/2\pi$$
$$=[p+(p-q)]/2\pi,$$

which is higher than that of either of the components.

Case 3. *The frequency when the component amplitudes are equal.* This case, because it yields easily to mathematical treatment, is often developed in elementary textbooks. When $A=a$ the resultant vibration may be expressed in the form

$$y=2a\cos\left[\frac{p-q}{2}t+\delta'\right]\sin\left[\frac{p+q}{2}t-\delta'\right],$$

which has a definite frequency, the arithmetic mean of that of the components.

These differences in frequency may be detected when listening to beats produced by two tuning forks, but it is very difficult to judge how much of the sound heard at the minimum is due to overtones. A more direct way of detecting the effect is to measure the distance from crest to crest in oscillograph pictures of beats. For example, measurements made on the beat tone photograph in D. C. Miller's *Science of Musical Sounds*,[3] using the time scale shown on the photograph, show that component frequencies, 2304 and 2048 vib/sec, yield a frequency of 2200 vib/sec at the maximum of the beats and 2600 vib/sec at the minimum amplitude. By measuring the amplitudes and substituting in the equations derived for Cases 1 and 2, one arrives at the same values within the limits of the measurements.

An interesting result of this fluctuation of frequency is that most oscillographic curves of beats show sharp lines at the maxima and blurred ones at the minima. If the rotating mirror or sweep circuit is in synchronism with the resultant frequency at the maximum, it is not at the minimum.

[3] D. C. Miller, *Science of Musical Sounds* (Macmillan, 1926), p. 183.

Grandeur consists in form, and not in size; and to the eye of the philosopher, the curve drawn on a paper two inches long is just as magnificent, just as symbolic of divine mysteries and melodies, as when embodied in the span of some cathedral roof.—CHARLES KINGSLEY

The Postprandial Proceedings of the Cavendish Society. I

JOHN SATTERLY
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IN *A History of the Cavendish Laboratory*,[1] J. J. Thomson writes a chapter on a "Survey of the Last Twenty-five Years", in which he remarks, on page 96:

> By 1898 the number of research students had increased so much that they decided to celebrate the event by a dinner, and the first of what has proved to be an uninterrupted series of such gatherings was held in December, at a restaurant in Sidney Street. I remember that during the songs after dinner, the Proctors[2] came to enquire what the proceedings were about; they did not, however, penetrate to the room where we were dining, being, I suppose, impressed and I have no doubt, mystified by the assurance of the landlord that it was a scientific gathering of research students. It was at this dinner that Langevin sang the "Marseillaise" with such enthusiasm that one of the waiters, a Frenchman, was moved to tears and wished to fall upon his neck and embrace him. Now that the number of old research students is so large these dinners, like the "Old Boys" dinners at a college, afford opportunities of meeting old friends, and help to establish a connexion between the past and present workers in the Laboratory. In recent years, a notable feature of these gatherings has been the songs specially composed for the occasion by members of the Laboratory; they deal with topical matters, personal or scientific, and are set to some well-known air.

Mr. A. A. Robb—a mathematician of St. John's College, writer on "Time and Space" and "Conical Space," a quiet Ulster man—was the rhymester of many of these songs; and very good they are, containing in many cases good sound physics in a form easy to remember. If a notable physicist, perhaps an old Cavendish man, were invited as a second guest to the dinner, Robb would make up a ditty in his honor. My diary shows me that at the 1908 dinner there were present, besides J. J. Thomson, E. Rutherford as a second guest, and, in addition, R. Threlfall, W. C. D. Whetham and T. C. Fitzpatrick.

The songs were not, however, limited to physics. Men who had passable voices sang well-known airs such as "John Peel," "To Anthea," "The Keys of Heaven," "Off to Philadelphia in the Morning," "Down among the Dead Men" (this was a favorite of Barkla's who had a good bass voice and was at one time in the choir of King's College Chapel), and the well-known "Widecombe Fair" (with its chorus of "With Bill Brewer, Jan Stewer, Peter Gurney, Peter Davy, Dan'el Whiddon, 'Arry 'Awk, Old Uncle Tom Cobley and all"). I well remember J. J., with a cigar in his mouth, bow tie all askew, eyes gleaming with merriment, beating out the chorus of his favorite song about the Old Mare as each rider was named. Another remembered scene is that of the dinner of 1909 when L. Vegard (of Aurora fame) gave a Norwegian action song and dance. Those were the days when we men contributed all the gaiety ourselves. The dinners were always held in licensed premises or in College, and the liberal libations of wine loosened our tongues so that no professional artists were required to fill up the evening. Often we got as much fun out of the singer as out of the song.

The favorite toast was, of course, to our Professor, the "pride of us all." Another favorite, due I think, in the first case, to Vinycomb, was to "The White Man's Burden, or hanging on to one job while trying to get another," an occupation that annually occurs in research laboratories towards the end of the academic year.

Now for the songs themselves.[3] I give them below in chronological order adding a few words of explanation as far as I think necessary. I was at the Cavendish Laboratory from 1903 to 1912 and my diary will aid me.

Ions Mine.—This was written in 1900 (revised in 1904) by Professor J. J. E. Durack of

[1] The Cavendish Laboratory of Cambridge University, England. The history, published by Longmans Green and Company in 1911, covers the period from 1871 to 1910.

[2] University dons appointed to look after the behavior of undergraduates, especially after dark. They wander around the University town followed immediately by two "bulldogs" (tall sturdy men who carry out the proctors' orders) and woe betide the undergraduate who is found without cap and gown or who is smoking. For either offence he is sent to his room and fined six and eight pence.

[3] Every three or four years the songs were reprinted privately to keep them from oblivion; the fifth and sixth editions, however, were published by Bowes and Bowes, Cambridge.

Cavendish research students in 1909: L. Vegard, J. Stead, J. R. Wilton, H. H. Paine, G. I. Taylor; H. Thirkill, R. Whiddington, L. Southerns, J. M. Adams, E. M. Wellisch, C. S. Wright, R. T. Beatty; G. W. C. Kaye, T. H. Laby, H. Erikson, W. Borodowsky, H. V. Gill, D. M. Bose; J. A. Crowther, F. Horton, D. B. Pearson, J. J. Thomson, E. R. Laird, N. R. Campbell, J. Satterly; A. L. Hughes, J. A. Orange, R. D. Kleeman.

Allahabad, India, and was first sung by the author. It is one of the favorites, being easy to remember and containing much interesting physics. The fourth stanza is often attributed to J. J. Thomson himself and, for this reason, is usually sung more respectably in a minor key. The "Sir William" of the last verse is Sir William Ramsay, who was awarded a Nobel prize in 1904 for his work on helium and other rare gases.

IONS MINE

Air: "Clementine."

1 In the dusty lab'ratory
'Mid the coils and wax and twine,
There the atoms in their glory
Ionize and recombine.

Chorus Oh my darlings! Oh my darlings!
Oh my darling ions mine!
You are lost and gone for ever
When just once you recombine!

2 In a tube quite electrodeless,
They discharge around a line,
And the glow they leave behind them
Is quite corking for a time.

3 And with quite a small expansion,
1.8 or 1.9,
You can get a cloud delightful,
Which explains both snow and rain.

4 In the weird magnetic circuit
See how lovingly they twine,
As each ion describes a spiral
Round its own magnetic line.

5 Ultraviolet radiation
From the arc or glowing lime,
Soon discharges a conductor
If it's charged with minus sign.

6 α rays from radium bromide
Cause a zinc blende screen to shine,
Set it glowing, clearly showing
Scintillations all the time.

7 Radium bromide emanation,
Rutherford did first divine,
Turns to helium, then Sir William
Got the spectrum—every line.

The Radium Atom.—Written by Horton and sung by Durack in 1904, this song was another early favorite. The "corpuscle" is the early name of what we moderns call the electron. N. R. Campbell and the present writer had been having trouble that term while making up needles for Dolezalek electrometers. Metal-coated tea-wrapping paper was used and, as the workman in charge of supplies had placed the paper in his desk among all sorts of odds and

ends, it had got contaminated with radioactive substances, with the result that unwanted leaks occurred within the electrometer cases. Much time was spent in tracing the cause, and the author of the song apparently heard the experimenters giving way to their feelings. A. S. Mackenzie of Johns Hopkins, later of Dalhousie University, Nova Scotia, had to go down into the cellar to work in order to be free from radioactive interference. In those early days it was not known how much trouble diffusing emanation might produce.

THE RADIUM ATOM

Air: "The Tarpaulin Jacket."

1 A radium atom was dying,
And just ere it burst up for aye,
Corpuscles, which round it were flying,
These last dying words heard it say—

Chorus Oh, I am a radium atom,
In pitchblende I first saw the day,
But soon I shall turn into helium:
My energy's wasting away.

2 About the laborat'ry latterly
I always have seemed in the way;
I've worried both Campbell and Satterly[4]
And many bad things made them say.

3 I often have got in a frenzy,
As down in the cellar I lay,
Being tortured by Huff or Mackenzie[5]
Deflecting my poor α-ray.

4 The theories about my interior
Proposed by the men of today,
Would make me appear quite inferior—
A crowd of corpuscles at play.

5 When wishing to be in the fashion
My γ-corpuscle they slay,
And state that, according to Paschen,[6]
'Tis merely a swift β-ray.

6 Through me they say life was created
And animals formed out of clay,
With bouillon I'm told I was mated
And started the life of today.[7]

7 To build up my weak constitution
I'm trusting myself to J. J.,
He'll get the most truthful solution
Of all who have entered the fray.

8 My temperature's very unsteady,
I'm losing in weight every day;
But if the end's near I am ready—
At least, life's been lengthy and gay!

[4] N. R. Campbell and J. Satterly, "On the use and abuse of radioactive needles for delicate electrometers," Proc. Cav. Lab., Oct. and Nov. (1904).

[5] A. S. Mackenzie, Phil. Mag. **10**, 538 (1905).

[6] F. Paschen, Physik. Zeits. **5**, 563 (1904).

[7] Daily Chronicle, June, July and Aug., 1905; Punch, July 12, 1905.

The Revolution of the Corpuscle.[8]—J. J. says:[9] "One of the most successful of these songs written by Mr. Robb is printed below. For the benefit of nonmathematical readers it should be explained that the chorus represents the way in which 'Maxwell's equations,' the foundations of modern electromagnetic theory, would be pronounced, which the marvellous ingenuity of the author has succeeded in adapting to the needs of the rhythm."

THE REVOLUTION OF THE CORPUSCLE

Air: "The Interfering Parrot" (*The Geisha*).

1 A corpuscle once did oscillate so quickly to and fro,
He always raised disturbances wherever he did go.
He struggled hard for freedom against a powerful foe—
An atom—who would not let him go.
The æther trembled at his agitations
In a manner so familiar that I only need to say,
In accordance with Clerk Maxwell's six equations,
It tickled people's optics far away.
You can feel the way it's done,
You may trace them as they run—
$d\gamma$ by dy less $d\beta$ by dz is equal $K \cdot dX/dt$
. . . . . .
. . . . . .
While the curl of (X, Y, Z) is the minus d/dt of the vector (a, b, c).

2 Some professional agitators only holler till they're hoarse,
But this plucky little corpuscle pursued another course,
And finally resorted to electromotive force,
Resorted to electromotive force.
The medium quaked in dread anticipation,
It feared that its equations might be somewhat too abstruse,
And not admit of finite integration
In case the little corpuscle got loose.
For there was a lot of gas
Through which he had to pass,
And in case he was too rash,
There was sure to be a smash,
Resulting in a flash.
Then $d\gamma$ by dy less $d\beta$ by dz would equal $K \cdot dX/dt$
. . . . . .
. . . . . .
While the curl of (X, Y, Z) would be minus d/dt of the vector (a, b, c).

3 The corpuscle radiated until he had conceived
A play by which his freedom might be easily achieved;
I'll not go into details for I might not be believed,
Indeed, I'm sure I should not be believed.
However, there was one decisive action;

[8] This song, written by A. A. Robb in 1905, has been reprinted in some physics texts; e.g., in *A Survey of Modern Physics*, by G. F. Hull.

[9] Reference 1, p. 97.

The atom and the corpuscle each made a single charge,
But the atom could not hold him in subjection,
Though something like a thousand times as large.
The corpuscle won the day,
And in freedom went away,
And became a cathode ray.
But his life was rather gay,
And he went at such a rate
That he ran against a plate;
When the æther saw his fate
Its pulse did palpitate.
And $d\gamma$ by dy less $d\beta$ by dz was equal $K \cdot dX/dt$
. . . . . .
. . . . . .
While the curl of (X, Y, Z) was the minus d/dt of the vector (a, b, c).

J. J.—Written by A. A. Robb in 1905, this song contains references to the theft of overcoats from laboratories (which is, therefore, not a postwar disease), to the fact that some research men marry before getting their graduate degrees (which is not always wise), and to the idea that some men get old before they get a good job, while others develop crankiness (which makes one believe that a purely research existence is not necessarily the best).

It is hard for research men of more modern days to believe that at the time this song was written a busy research laboratory, such as the Cavendish, possessed only one voltmeter for testing the batteries of little 2-v cells contained in the four cases which were distributed through the laboratory, and only one mechanical pump—an old Fleuss oil pump worked by the foot. With many men working on ionization currents, these essential pieces of apparatus traveled every day many times around the laboratory. The connections of the cells were continually coming apart and Rolph (the handy man) or the researcher himself had to get busy with the soldering iron. For better degrees of vacuum than the Fleuss pump could manage, the Töpler mercury pump was the only apparatus available; and men spent all day lifting and lowering vases of mercury, each weighing 40 to 50 lb.

E. Everett was J. J. Thomson's private assistant. He had no knowledge of theory but was a good glass blower. The University of Cambridge gave him an honorary M.A. when he retired. Hayles was the lecture assistant. He pronounced his name "Hiles." (Cambridge is almost in the Cockney region.)

J. J. directed the whole laboratory—undergraduate and research—managed the finances himself with the aid of Hayles and Rolph, paid the checks to everyone personally, and did it all without even a typewriter. What a change from laboratory conditions of today!

"J. J."

Air: "Solomon Levi."

1 My name is J. J. Thomson and my lab's in Free School Lane,
If once a man has been inside he's sure to come again,
Here some do play with Töpler pumps, and some with liquid air,
And some do play the giddy goat, but that's not here nor there.

Chorus Oh! J. J. Thomson, J. J. Tra-la-la-la,
Sir Joseph Thomson, Tra-la-la-la-la-la-la-la-la-la-la,
My name is J. J. Thomson, and my lab's in Free School Lane,
There's no professor like J. J. my students all maintain,
I've been here six and twenty years, and here I shall remain,
For all the boys just worship me at my lab in Free School Lane.

2 I've got a lot of two-volt cells that sometimes need repair,
I've got some electrometers that sometimes make me swear;
But when I'm sure a leak's not due to ultraviolet light,
I hand the thing to Everett, who always puts it right.

3 When once or twice a week I go to play a game of golf,
I leave the apparatus safe in charge of Mr. Rolph,
And Lincoln, too, in case you want a glass tube or a flask,
Will drop his work immediately and get you what you ask.

4 When I give a public lecture nothing ever does go wrong,
For Everett is always there to help the thing along,
And there, too, in the corner, with his visage wreathed in smiles,
Sits my other good assistant, the genial Mr. Hayles.

5 The people are delighted with the wondrous things we do,
But few have any notion that we're such a jolly crew.
If some of them were here tonight I think we'd make it plain
We're not all just as dry as dust at the lab in Free School Lane!

The Radiobe.—Written in 1906 by Robb, this song commemorated a great discussion going on, especially in the popular press of the day, on the origin of life.[10] J. B. Butler Burke was active in this matter and claimed, from his experiments, that putting radioactive matter in sterilized bouillon caused spontaneous generation of life. He even wrote a book on the subject. Burke worked on and off in the Cavendish so that the name of the laboratory got dragged into the papers; and another of the Cavendish men, N. R. Campbell, became very angry and expostulated. Robb rather enlarged on what actually happened. The "Whewell's Court" is a court in Trinity College, named after the great Whewell, a former Master of Trinity. Rolph was the laboratory handy man, a most willing helper and one to whom all the early workers were much indebted. He charged the two-volt cells in the large cabinets and made liquid air on a Hampson machine day after day, and in those days with a noisy gas engine driving the compressor it was no sinecure.

THE RADIOBE

Air: "The Amorous Goldfish" (*The Geisha*).

1 A radiobe swam in a bowl of soup
As dear little radiobes do,
And Butler Burke gave a wild war whoop
As he over his microscope did stoop,
And it came in the field of view.
He said: "This radiobe clearly shows
How all the forms of life arose;
And further plainly shows," said he,
"What a very great man is J. B. B.!
For from radiobes I re-iter
Spring the false world's pomp and glitter,
From the elephant big
To the little earwig,
And the birds that twit-twit-twitter."

2 There lived apart in the Whewell's Court
A son of the Campbell clan,
And when he heard this strange report
He thought it would be magnificent sport
To attack this illustrious man.
And so arose an awful strife
About the "Origin of Life,"
For he did not think Burke's theory true
And he hinted this in his review.
And his words were bit-bit-bitter,
They provoked a tit-tit-titter.
And Burke took a cab
To the Cavendish lab
To slay this crit-crit-critter.

3 Now Campbell worked in a room downstairs
In the lab in Free School Lane,
And Burke slipped in quite unawares,
And seized him by his scanty hairs,
And he called on him to explain.
The language used I need hardly say
Was such as is not heard every day;
And you'll agree it would be wrong
To give the details in my song.
For the strife was bit-bit-bitter,
For the prize ring fit-fit-fitter,
Bringing Rolph to the room
With a great big broom
To remove the lit-lit-litter.

The Don of the Day.—This song was set to a very popular tune and took the house by storm. It is one of Robb's best. The Professor was known to the general public in those days as the man "who split the atom." The chemists of the older school were greatly depressed by this form of iconoclasm.

Verse 4 contains a reference to the tea we had every afternoon. At 4:30 Rolph carried into the Professor's room a pot of tea, milk, a dish of Osborne biscuits, and an array of cups and saucers. To that room we repaired and spent, say, fifteen minutes in gossip. Usually J. J. went for a walk after a late lunch, dropped into the Union to hear the latest news, or visited the football field to see a Rugby match, so that he usually had something to relate. He sat on his stool (there was no chair at his desk) and swiveled around to laugh with us all. One could tell many tales of the jokes that happened at tea time but must refrain.[11] After 4:50 we went off again to our experiments and often did as much between that time and 6 o'clock—the closing time—as we had done earlier in the afternoon. It was J. J.'s practice to visit every research man about twice a day for consultation and to give advice.

[10] See verse 6 of "The Radium Atom."

[11] One tea story I must relate. We were discussing the Oxford and Cambridge boat race and the late Professor H. A. Bumstead of Yale mentioned that in America railways ran alongside the river on which the Harvard-Yale race was rowed, thus enabling spectators to follow the contest from start to finish. J. J. burst out, "Oh, is that how fast your trains go?" "No," replied Bumstead, "that's how fast our crews row." J. J. laughed as heartily as the rest of us at the neat bit of repartee.

The 1906 dinner at the Trocadero Restaurant.

THE DON OF THE DAY

Air: "Father O'Flynn."

1 Of Dons we can offer a charming variety,
All the big pots of the Royal Society,
Still there is no one of more notoriety
Than our professor, the pride of us all.
Here's a health to Profesor J. J.!
May he hunt ions for many a day,
And take observations,
And work out equations,
And find the relations
Which forces obey.

Chorus Here's a health to Professor J. J.!
May he hunt ions for many a day,
And take observations,
And work out equations,
And find the relations
Which forces obey.

2 Our worthy professor is always devising
Some scheme that is startingly new and surprising,
In order to settle some question arising
On ions and why they behave as they do.
Thus, when he wants to conclusively show
Some travel quickly and some travel slow,
He brings into action
Magnetic attraction
And gets a deflection
Above or below.

3 All preconceived notions he sets at defiance
By means of some neat and ingenious appliance,
By which he discovers a new law of science
Which no one had ever suspected before.
All the chemists went off into fits;
Some of them thought they were losing their wits,
When quite without warning
(Their theories scorning)
The atom one morning
He broke into bits.

4 When the professor has solved a new riddle,
Or found a fresh fact, he's fit as a fiddle,
He goes to the tea room and sits in the middle
And jokes about everything under the sun.
Then if you try to look grave at his jest,
You'll burst off the buttons which fasten your vest,
For when he starts chaffing,
Though tea you be quaffing,
You cannot help laughing
Along with the rest.

An Emanation.—This song was written by Robb in 1906, at the time when Thomson was awarded the Nobel prize. The dinner was held just after his return from Sweden and in honor of the occasion. To give some of those who had passed through the laboratory a chance to participate in the felicitations, the scene was changed to the Trocadero Restaurant at Piccadilly Circus in London. It was a tumultuous occasion. In the photograph the chairman, Frank Horton of St. John's College, is shown, standing, J. J. being seated on his right. Also in the picture are two

Americans, D. F. Comstock and L. T. More; an Australian who settled in the United States, R. Kleeman; one Canadian, H. F. Dawes; and the writer.

AN EMANATION

Air: "Chon-Kina" (*The Geisha*).

1 I'm the smartest of professors in the town,
You should see me in my college cap and gown,
At some learned Association
When I give a great oration
And I'm covered with a halo of renown.
O'er the scientific world I hold my sway,
And it hearkens unto every word I say.
But there comes a dinner yearly,
'Tis a thing I love most dearly
For they treat me there in quite another way.

Chorus John Joseph, John Joseph, John, John, Joseph, Joseph,
That is what they call me at the dinner once a year.

2 The structure of the atoms I explain
By the number of corpuscles they contain;
Which, according to my notion,
Are in very rapid motion,
Though the speed of light they never quite attain.
They've a mass two-thirds of e^2 over a,
But I'll give you more details another day,
For I'm feeling so elated
With the way I have been fêted
That my sole desire is just to hear you say:
John Joseph, etc.

3 For reasons which I'll leave you to surmise
'Twas decided I should get the Nobel prize,
So they called me off to Sweden,
And I thought I was in Eden—
Oh you should have seen the sparkle in my eyes!
My diploma neatly fastened with a string
Was presented by His Majesty the King,
But no sooner was it over
Than I crossed the Straits of Dover
To be present at the dinner where they sing:
John Joseph, etc.

(*To be continued in the August issue.*)

Reproductions of Prints, Drawings and Paintings of Interest in the History of Physics

6. Eminent Men of Science of Great Britain Living in the Years 1807–1808

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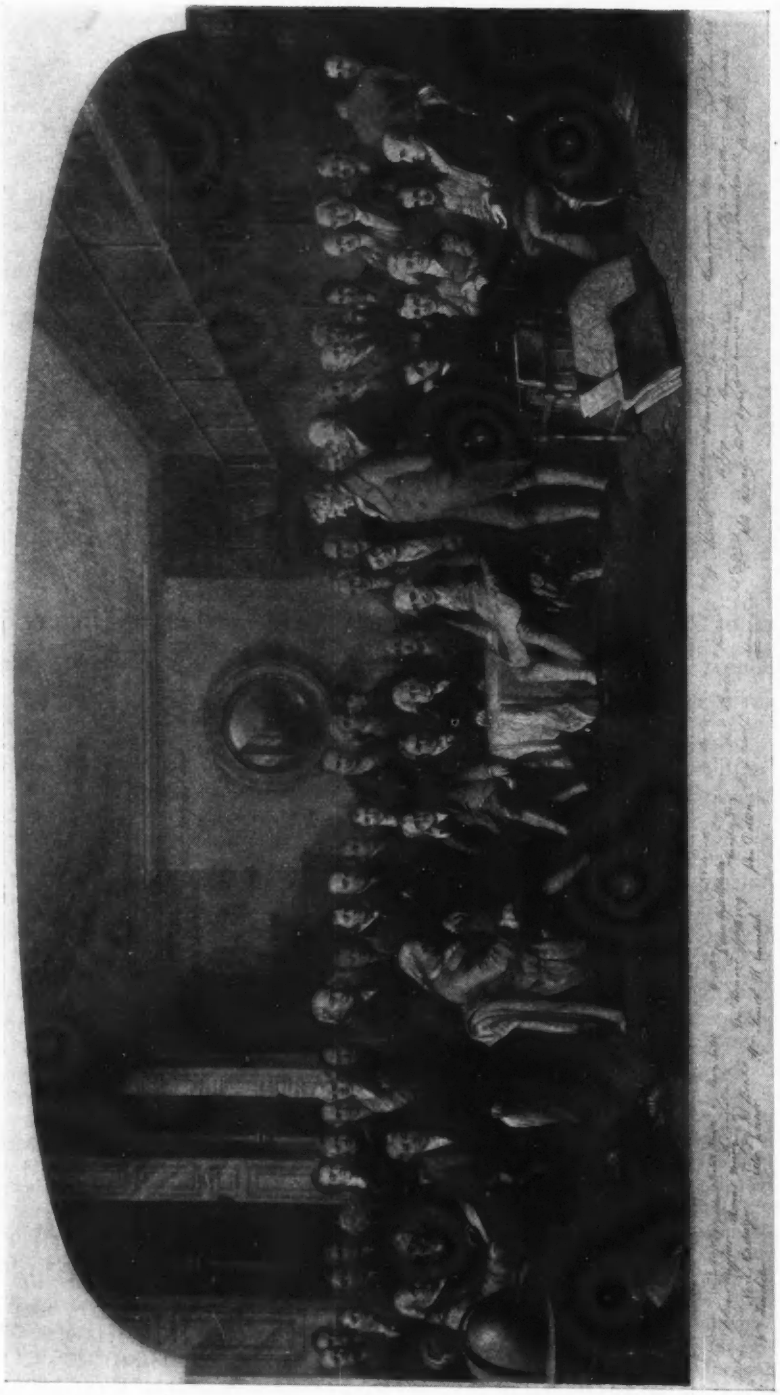
THE nineteenth century has often been called the century of science. It is interesting therefore to have the century's own selection of the most distinguished scientists living at the beginning of that period. The group of 51 men, shown in this reproduction assembled in the Library of the Royal Institution in London, represents the judgment of the 1860's as to those who were the most eminent men of science in Great Britain during the years 1807–1808. Reading from left to right they are:

Seated

Sir William Herschel (1738–1822)
Nevil Maskelyne (1732–1811)
Edward Jenner (1749–1823)
Henry Cavendish (1731–1810)
John Dalton (1766–1844)
Sir Marc Isambard Brunel (1769–1849)
Matthew Boulton (1728–1809)
Joseph Huddart (1741–1816)
James Watt (1736–1819)
Samuel Crompton (1735–1827)
Charles Tennant (1768–1838)
Edmund Cartwright (1743–1823)
Sir Francis Ronalds (1788–1873)
Charles, third Earl Stanhope (1753–1816)

Standing

Francis Baily (1774–1844)
W. J. Frodsham
Sir John Leslie (1766–1832)
John Playfair (1748–1819)
Daniel Rutherford (1749–1819)
Peter Dollond (1730–1820)
Thomas Young (1773–1829)
Robert Brown (1773–1858)
Davies Giddy Gilbert (1767–1839)
Sir Joseph Banks (1743–1820)
Henry Kater (1777–1835)
William Smith (1769–1839)
Edward Charles Howard (1774–1816)
William Allen (1770–1843)
William Henry (1775–1836)
William Hyde Wollaston (1766–1828)
Charles Hatchett (1765–1847)
Humphry Davy (1778–1829)
Henry Maudslay (1771–1831)
Sir Samuel Bentham (1757–1831)
Richard Watson (1737–1816)
Count Rumford (1753–1814)
Thomas Telford (1757–1834)
William Murdock (1754–1839)
John Rennie (1761–1821)
William Chapman (1749–1832)
William Jessop (1745–1814)



Eminent men of science of Great Britain living in the years 1807–1808.

Robert Mylne (1734–1811)
Sir William Congreve (1772–1828)
Bryan Donkin (1768–1855)
Edward Troughton (1753–1835)
Thomas Thomson (1773–1852)
William Symington (1763–1831)
Patrick Miller (1731–1815)
Alexander Nasmyth (1758–1840)
Joseph Bramah (1748–1814)
Richard Trevithick (1771–1833)

The first half of the nineteenth century saw the culmination of the industrial revolution and so it is not surprising that more than half of the men selected for inclusion in this print were industrialists, engineers and inventors, and that, among the remainder, workers in physics and chemistry predominate. Only four of the 51—BANKS, BROWN, JENNER and RUTHERFORD—can be assigned to any of the life sciences, while mathematics has only two representatives, LESLIE and PLAYFAIR, and even these were more distinguished in physics than in pure mathematics.[1] Pure science is not unrepresented, however, or even relegated to the background, for positions of prominence are given to CAVENDISH, DALTON, HERSCHEL and YOUNG. The relatively small prestige of the universities, particularly of Oxford and Cambridge, is also noteworthy. Only four of the 51 scientists portrayed held university positions and, of these, two were professors at Edinburgh, one at Glasgow and one at Cambridge. Moreover, less than 20 of the 51 were university trained, and, of these, more than half received their education at the Scottish universities, particularly Edinburgh.

The reproduction was made from a large (20×41-in.) mezzotint engraving by WILLIAM WALKER and G. ZOBEL which was published in 1862 by William Walker and Son. The pencil and wash drawing on paper, from which the engraving was made, now hangs in the National Portrait Gallery in London; the figures were drawn by FREDERICK SKILL, the grouping was designed by SIR JOHN GILBERT, and the whole was finished by WILLIAM WALKER and his wife ELIZABETH; the greatest care was taken to make each figure in the group an actual portrait; four years of careful study were spent upon it. It affords us the only likenesses we have of several quite important applied scientists.

[1] Of the low state of mathematical science at this time Sir John Herschel wrote: "The end of the eighteenth and the beginning of the nineteenth century were remarkable for the small amount of scientific movement going on in this country, especially in its more exact departments. . . . Mathematics were at the last gasp, and Astronomy nearly so—I mean in those members of its frame which depend upon precise measurement and systematic calculation. The chilling torpor of routine had begun to spread itself over all those branches of science which wanted the excitement of experimental research."

A P-V-T Diagram of the Allotropic Forms of Ice

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FROM the data published by Bridgman[1] concerning his high pressure researches on water it is possible to plot with but few interpolations and extrapolations a P–V–T diagram of the allotropic forms of ice. Such a diagram is shown in Fig. 1. It is an isometric projection, drawn to scale, of the thermodynamic surface of water in its stable liquid and solid phases. The volumes indicated are those for 1 kg of water at temperatures ranging from −40° to 110°C and at pressures from zero to 25,000 kg/cm².

The three-dimensional representation provides an effective means of acquiring an orientation among the P–V–T interrelations. One can see at a glance the pressure and the temperature ranges of the various kinds of ice. The isobars and the isotherms drawn on the diagram indicate

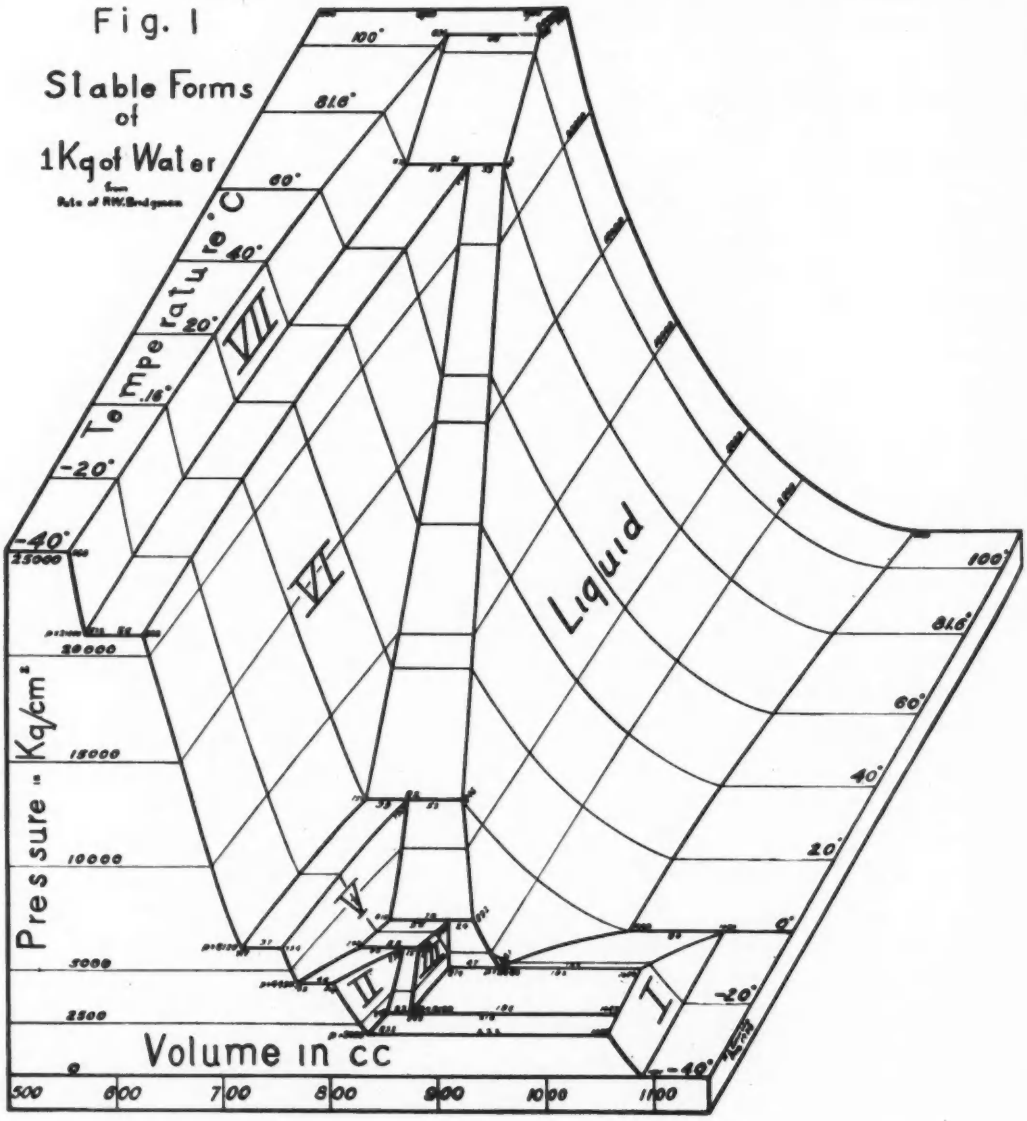
[1] P. W. Bridgman, Proc. Am. Acad. **47**, 441 (1911–1912); J. Chem. Phys. **5**, 964 (1937).

TABLE I. *Triple points.*

PHASES	PRESSURE (KG/CM²)	TEMPERATURE (°C)	VOLUME CHANGES (CM³/KG)
Liquid I, vapor	0.01	0.01	90, 10^8, 10^8
III, liquid, I	2,115	−22.0	47, 135, 182
II, III, I	2,170	−34.7	22, 196, 218
V, III, liquid	3,530	−17.0	55, 24, 79
V, II, III	3,510	−24.3	40, 15, 55
VI, V, liquid	6,380	0.16	39, 53, 92
VII, VI, liquid	22,400	81.6	58, 33, 91

the respective volume changes at various pressures and temperatures. The pressure and the volume coefficients may be approximately computed and their rates of change with temperature observed. The triple-point transitions can hardly be made clear without a three-dimensional figure. The diagram shows the three volume changes possible at the triple points, and makes evident the fact that one of the volume changes at any given triple point must be the sum of the other two. In Table I are listed the pressures, temperatures, and volume changes for the known triple points. The P–T relations, shown in Fig. 2, are obtained by projecting the melting and the transition curves on a P–T plane.

A number of interesting features concerning the properties of water may be discussed in



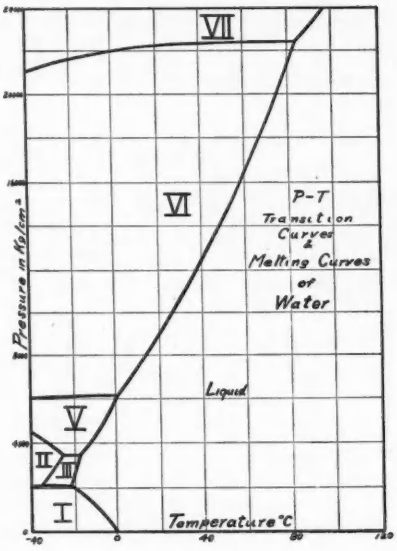


FIG. 2. P–T transition and melting curves for water.

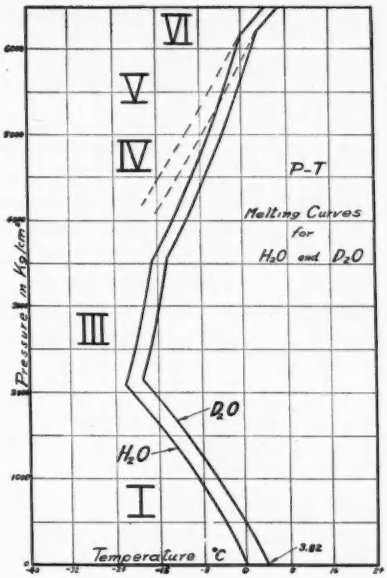


FIG. 3. P–T melting curves for H_2O and D_2O.

connection with Fig. 1. An inspection of the volume coordinates reveals directly that ice I—ordinary ice—is the only ice for which the specific volume may be larger than 1000 cm^3/kg; that is to say, the only ice with a specific gravity smaller than 1. An isochore through 0°C, corresponding to the case of water being cooled in a constant-volume container, discloses that the water will be a mixture of liquid and ice I down to −22°C. Below −22°C there will be a mixture of ice I and ice III as far as −34.7°C, when ice II replaces ice III. These remarks refer, of course, only to stable phases. The height or pressure coordinate of the ice I plateau indicates a maximum expansive pressure of freezing water, namely, about 2200 kg/cm^2. It can be seen, too, that water cannot exist as liquid in stable form below −22°C, no matter how high the pressure.

At body temperatures water may exist as a solid in the form of ice VI at pressures of approximately 10,000 kg/cm^2. That the molecular forces within human-tissue colloids may compress the water in the tissues to form ice VI is suggested by experiments performed in the Paris Institute of Physico-chemical Biology.[2]

[2] Neda Marinesco, Science **75**, 9, Supplement (Jan. 22, 1932).

No new form of ice has been found at pressures up to 50,000 kg/cm^2; that is to say, the diagram of Fig. 1 could be extended to twice its height or pressure range without showing a new triple point.

Figure 3 shows the melting curves for heavy water over the range of values reported by Bridgman[3] alongside those for ordinary water. The dotted lines indicate the transition region to ice IV, an unstable variety of both D_2O and H_2O not shown in Fig. 1.

Very recently another unstable form of ice, labeled ice VIII, has been reported [4] as being obtained from mixtures of water with organic liquids at atmospheric pressure. The melting point is given as about −7°C, and the density as slightly larger than that of water. The most distinctive feature of ice VIII is that it crystallizes regularly. Neither ice I nor the other ices whose crystalline structures have been investigated[5] have a regular structure.

[3] P. W. Bridgman, J. Chem. Phys. **3**, 597 (1935).
[4] E. Cohen and C. J. G. van der Horst, Zeits. f. physik. Chemie **B40**, 231 (1938).
[5] R. L. McFarlan, J. Chem. Phys. **4**, 60, 259 (1936).

A Photographic Method for the Study of Accelerated Motion

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MOST of the apparatus commonly employed to illustrate the various types of accelerated motion fail to show the step-by-step change in velocity. It is customary to integrate the differential equation of motion and obtain an expression for the distance covered in a relatively long period of time, and then to test this expression. There is a pedagogic value, however, in showing the student a record of the gradual change in velocity which is involved. Some devices, such as the falling tuning fork, the spark-timing free-fall apparatus and the high speed motion picture camera, do achieve this goal. The apparatus described in this paper involves similar principles, makes use of parts already available in every laboratory and has the added advantage that at the end of the experiment the student is supplied with a permanent record, convenient in size, of the type of motion investigated.

The method employed was to photograph, at equal short intervals of time, the consecutive positions of a self-luminous object which moves near a graduated scale. The moving object consisted of a single cell enclosed in a cylindrical case, a socket attached to the side of the case, and a flashlight lamp which served as the luminous source. Since the lamp was on the side of the case, it was possible to bring it quite close to the edge of a meter stick placed in a vertical position, and to move it alongside this scale. The meter stick can be illuminated by the lights from the room or a desk lamp. A sharp image of the meter stick was focused on the ground glass screen of a camera. This image was about 15 cm long, and it is not advisable to reduce it further if clear millimeter readings are desired on the photograph. A disk of black cardboard with a narrow slot cut near the periphery was mounted on the shaft of a synchronous motor near the camera lens. As the disk rotated the slot was brought in line with the lens 30 times/sec. The width of the slot was adjusted to give exposures of 1/2000 sec. The photographs reproduced in Figs. 1 to 3 were taken on Eastman Panchro-Press films, although higher speed films are now available. The procedure was to rotate the disk, and then open the camera shutter so that the position of the flashlight was photographed at intervals of 1/30 sec during its motion alongside the meter stick. The shutter was left open for an additional 20 or 30 sec in order to produce a clear image of the meter stick.

The camera used had a 5×7-in. plate holder, but an adapter was inserted to hold a 2×7-in. film. The lens was a simple anastigmat with a 5.8 opening. It is not essential to use a lens of high quality as any distortion of scale affects the separation of the marks on the meter stick as much as it does the spacing of the images of the lamp, and all measurement of the image positions are made by direct correlation with the meter stick markings. The center of each image can be located to within 0.5 mm by means of either a hand lens or a microscope with cross hair, or by projecting the image on a screen and using a set square.

The flashlight case was suspended by two threads passing over light pulleys and tied to a weight. This ensured that, during the fall of the flashlight, the line of motion of its filament would remain coplanar with the face of the meter stick. For free fall the flashlight was released by burning the threads. A trace obtained for free fall is shown at a, Fig. 1. To show more simply, the manner in which the speed changes, another disk, which had two slots in it cut along radii 45° apart was used. The double dots in b, Fig. 1, are due to this arrangement. Calculations of g from measurements of these three sets of dots agree with one another to within 0.1 percent although the result is only within 0.5 percent of the local value. Least-square calculations[1] gave a somewhat better result.

The photographs obtained with a modified Atwood machine are shown in c to i, Fig. 1. With the mass m kept constant at 403.5 gm and weights hung on the other end of the thread to

[1] E. M. Pugh, Am. Phys. Teacher **4**, 70 (1936); P. Rudnick, Am. Phys. Teacher **4**, 217 (1936).

produce a driving force F of 10, 20 and 40 gm weight, respectively, the traces c, d and e were obtained. The accelerations a measured in the three cases were 21.34, 45.02 and 93.30 cm/sec². Since only a rough compensation for friction had been made, the equation

$$F-f=ma-Ia/r^2$$

was applied to the first two results, and the value of both the uncompensated force of friction f and the moment of inertia of the pulleys I were thus determined. (The latter was small, namely, 57 gm·cm² and, since the radius r of the pulley was 2.3 cm, the last term could be omitted without much loss of accuracy for students unfamiliar with rotary motion.) These values checked with the third set of measurements to within 1 percent.

Traces f and g, Fig. 1, are for the case where m was 605 gm, and F was 20 and 40 gm weight, respectively. By using the foregoing value of I, the new uncompensated force of friction was found for trace f, Fig. 1, in which the acceleration was 32.57 cm/sec². This checked within 2 percent for the trace g, where a was 65.83 cm/sec². A similar method yielded an accuracy of ¼ percent for the traces h and i, for which m was 807 gm, F was 20 and 40 gm weight, and a was 24.23 and 48.33 cm/sec², respectively.

A slight modification of the apparatus serves to illustrate the parabolic path and the independence of vertical and horizontal components

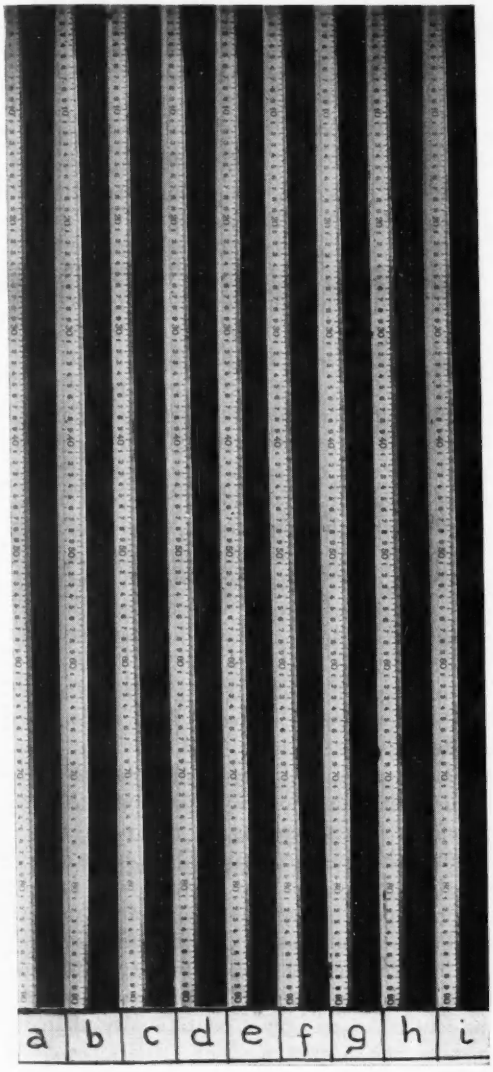

FIG. 1. (a) and (b): traces of a freely falling luminous object photographed at intervals of 1/30 sec; (c), (d) and (e): luminous object of mass $m=403.5$ gm moving under the action of forces $F=10$, 20 and 40 gm weight; (f) and (g): same, for $m=605$ gm, and $F=20$ and 40 gm weight. (h) and (i): same, for $m=807$ gm, and $F=20$ and 40 gm weight.

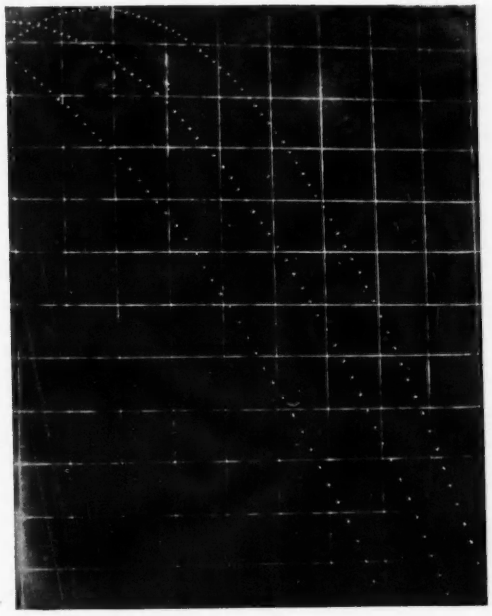

FIG. 2. Paths of a projectile photographed at intervals of 1/120 sec.

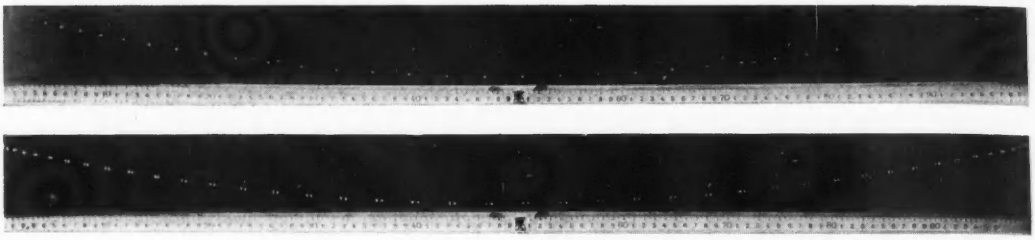

FIG. 3. Motion of a pendulum, photographed at intervals of 1/30 sec.

of the velocity in the motion of a projectile. The reference scale was a portable blackboard, cross-ruled with white lines 10 cm apart. The moving object, a flashlight with the bulb placed on the axis of the smooth cylindrical case, was rolled down a chute that could be adjusted to have an upward, horizontal or downward inclination at its lower end. The blackboard, placed against the end of the chute and illuminated by a desk lamp, was photographed through the rotating disk and then removed. The flashlight was now released so that the plane of its parabolic path after leaving the chute coincided with the plane previously occupied by the blackboard. To eliminate sidetracking and wobbling of the lamp, the flashlight case was wrapped in a long strip of paper placed on the chute and then unwound from this strip. A disk with four equally spaced slots was used in order to increase the number of images and bring out more clearly the shape of the curve. Fig. 2 shows three such projectile paths. For each of these, the number of dots between every pair of vertical lines remains the same, showing directly the constancy of the horizontal component of the velocity. The number of dots between consecutive pairs of horizontal lines may be used for a rough calculation of g.

This method does not easily lend itself to the study of rotary or periodic motion. Of course, the equation $L=I\alpha$ can be tested by using a flashlight tied to a string wound around the axle of an inertia wheel. The procedure is then similar to that for the modified Atwood machine. For the case of simple harmonic motion the easiest method is to use a pendulum and to photograph one-half of a complete oscillation. To obtain the photographs shown in Fig. 3, the flashlight was hung from two bifilar suspensions and the meter stick was placed in a horizontal position. The effective length of the pendulum was 205 cm. It was released at one end of the meter stick and stopped when it reached the other end. The trace obtained is shown in the upper part of Fig. 3. The lower part of the figure was obtained by using the disk with the two slots. These photographs show clearly the salient properties of simple harmonic motion, such as maximum velocity at the center of the path and maximum acceleration at the ends. Approximate accelerations at various points along the path are calculated from the positions of three neighboring images. A plot of acceleration *versus* angle of deflection, as obtained from Fig. 3, gave points only slightly scattered from a straight line. The slope of this line was only 2 or 3 percent higher than the value of g. The number of images on the photograph is 43, yielding a period for the pendulum of approximately 2.8 sec. as compared to the calculated value of 2.75 sec.

These experiments can be used effectively for lecture demonstration. By proper choice of the developer the processing of the plate can be accomplished in 2 to 3 min. This can be done in a light-tight bag in the lecture room and the film projected before the class, even in the wet condition, within a short time after the exposure. The apparatus can be adapted to the photography of various other types of linear motions, such as the motion of an object continuously changing in mass, the motion of spheres and streamlined objects in viscous mediums, and other cases of varying linear acceleration. However, these problems are not usually dealt with in the elementary course for which this apparatus was primarily designed.

Refractive Index of a Glass Plate by Multiple Reflections

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RECENTLY it has been found possible to replace the time-honored experiment,[1] "The Determination of the Refractive Index of a Glass Plate by Means of a Microscope," by an experiment of almost equal simplicity but of superior accuracy. According to the new procedure a glass plate is partially silvered on both sides with films as heavy as those employed in the Fabry and Perot interferometer. If the silvered glass plate be laid flat on the stage of a microscope and if a scratch E (Fig. 1) be illuminated brilliantly from below, it will be found that, as the microscope barrel is moved down slowly, a number of images of the scratch will come into focus successively. By determining the linear separation h of two adjacent images and the thickness of the plate t, the refractive index n may be evaluated at once from the relation $n=2t/h$.

The simple theory underlying this experiment is as follows. Any ray leaving E and making a small angle r with the normal suffers multiple internal reflections which produce the transmitted rays *1*, *2*, *3* originating in the virtual sources D, G, H. Since the angles made with the normal are very small, it is permissible to replace tangents by sines. It follows readily that:

$$\tan i = CA/CG = CB/CD$$
$$= (CA-CB)/(CG-CD) = 2CB/h = \sin i,$$
$$\tan r = CB/CE = CB/t = \sin r,$$
$$n = \sin i/\sin r = 2t/h.$$

The actual experiment was carried out with a microscope supplied with an 8×-eyepiece and with a glass plate 5–8 mm thick. Since the multiple images lie below the upper surface of the silvered plate, an objective having a relatively large working distance is required. None being available, the lowest component of the 16-mm objective was removed and, as a result, a working distance of about 5 cm was realized. The success of this method is determined by the degree of accuracy of focusing on the various images; hence, to overcome the inevitable depth of focus, a strip of metal 1 mm wide was mounted centrally under the objective lens. In consequence, images appeared double near the focus but became single at the focus. It was found that if the plane mirror of the microscope be used, the image of the filament of a 100-w Mazda lamp may be focused between the silvered surfaces and hence that this image, rather than a scratch in the silver, may be used as the source showing multiple images. A steel millimeter scale, attached to the barrel of the microscope, and a fixed pointer made it possible to record the position of the multiple images to 0.1 mm. The advantage derived from this mode of procedure over the older one[1] is that the total displacement of the microscope is so much greater that an eightfold increase in accuracy is realized.

Obviously, similar determinations of refractive indices of liquids may be made. It is merely necessary to bore a hole of about 5 mm diameter

TABLE I.

MATERIAL	t (MM)	NO. OF IMAGES	TOTAL MOTION OF MICROSCOPE (MM)	h (MM)	n	n (CHECK)
Crystal quartz (ord. ray)	4.79	5	24.8	6.20	1.545	1.544 (tables)
Glass	8.54	4	33.7	11.23	1.521	1.5216 (Abbe refractometer)
			33.6	11.20	1.525	

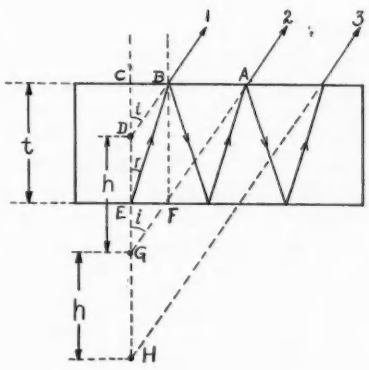

FIG. 1.

[1] Ames and Bliss, *A Manual of Experiments in Physics* (1898), p. 446.

through a brass disk 5 mm thick and to cover the openings with plates of platinized glass—the platinized surfaces facing one another. A suitable groove or hole is provided for the filling of this small cell. As a material for attaching the platinized plates, gelatine is quite satisfactory. The gelatine is allowed to dry for 24 hr, whereupon the cell is filled with, and immersed in, formaldehyde so as to render the gelatine insoluble in water. It is now permissible to fill the cell with aqueous solutions and organic liquids, but not with strong acids. The thickness of the cell is determined by filling it with distilled water (of known refractive index), measuring h and calculating t.

A few numerical examples are presented in Table I. From these and other results it would appear that the procedure here outlined transforms any microscope into a potential refractometer by means of which refractive indices, with no uncertainties short of the third decimal place, may be determined.

A Simple Method for Determining the Coefficient of Restitution

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THE two familiar equations for a head-on collision between two "imperfectly" elastic bodies are $m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$ and $e=(v_2'-v_1')/(v_1-v_2)$, where m_1 and m_2 are the masses of the two bodies, v_1 and v_2 are the velocities before impact, v_1' and v_2' are the velocities after impact, and e is the coefficient of restitution. Suppose m_2 is initially at rest so that $v_2=0$, and that the experimental conditions are such that, after impact, m_1 is at rest thus making $v_1'=0$. Then, $m_1v_1=m_2v_2'$ and $e=v_2'/v_1$, from which it follows that $e=m_1/m_2$; that is, under these experimental conditions the coefficient of restitution is equal to the ratio of the masses. Although this is the familiar result of a problem frequently found in texts on mechanics,[1] its use in an experiment devised to determine the coefficient of restitution does not seem to have found its way into any familiar literature.

The experiment, to determine e, as commonly performed,[2, 3] requires a rather expensive outlay, whereas the apparatus for the present experiment can be made inexpensive and simple. Inasmuch as the more elaborate apparatus[4] was available, however, it was used in order that the results obtained by the new method might be checked against those obtained by the ordinary method. In both methods the ball was released at an angle of about 15° to the vertical, striking at its lowest position a stationary horizontally suspended cylinder. For the ordinary method, the cylinder employed was of such mass that the ball would follow through with a diminished speed, whereas for the new method, the cylinder was of such mass that the ball would stop upon impact. Let us call these two methods the *follow-through* and *stop* methods, respectively.

In carrying out the follow-through method the data obtained were: the lengths s_1 and s_1' of the arcs through which the ball fell and rose; the arc s_2' through which the cylinder rose; and the masses m_1 and m_2 of the ball and cylinder. The original equations become $m_1s_1=m_1s_1'+m_2s_2'$ and $e=(s_2'-s_1')/s_1$, where the close approximation that the arc length is proportional to speed has been introduced. To obtain a measure of the accuracy of the method, the two members of the momentum equation were compared with their mean value.

In order to employ the stop method, a simple means for varying the mass of the cylinder must be provided. With the aid of a calculation involving an estimated value of e, a cylinder was chosen of such mass as to give a slight rebound after impact. A hole was bored along the axis of the cylinder and threaded. A threaded plug, made to fit this hole, was of such a length that threaded washers could be screwed on it, tight against the cylinder. By this means the position of the center of mass was not changed appreci-

[1] H. M. Dadourian, *Analytical Mechanics*, Problem 2, p. 322.
[2] R. A. Millikan, *Mechanics, Molecular Physics and Heat* (Ed. 1), p. 61.
[3] Taylor, Watson and Howe, *General Physics for the Laboratory*, p. 22.
[4] Reference 3, Fig. 21.

TABLE I. *Typical data.*

SURFACES:	FOLLOW-THROUGH METHOD						STOP METHOD		
	m_1(gm)	m_2(gm)	s_1(cm)	s_1'(cm)	s_2'(cm)	e	m_1(gm)	m_2(gm)	e
Steel ball on Steel cylinder	544	453	14.4	1.74	14.60	0.89±3%	544	625±20	0.87±3%
Brass cylinder	549	542	14.6	0.53	13.00	0.87±4%	549	644±35	0.85±5%
Brass cap							549	696±35	0.79±5%
Brass cap	228	198	14.4	2.24	12.81	0.74±4%	228	300±25	0.76±8%
Lead cylinder	228	499	17.8	1.20	7.29	0.34±3%	228	718±35	0.32±5%
Lead cap							228	827±35	0.27±4%

ably. The cylinder was adjusted, however, after each addition or subtraction of mass so that the centers of mass of ball and cylinder were in a horizontal line when at rest and the ball just touched the cylinder. The ball was pulled back through an arc of about 15° and watched carefully for a stop upon impact. With very little practice it is not too difficult to differentiate between a rebound, stop and follow-through of the ball. In order to get an estimate of the accuracy of this method, masses were added until there could be no question of a rebound and likewise subtracted until there could be no question of a follow-through. The percentage variation of the maximum or the minimum from the mean was taken as a measure of the accuracy of the method.

To obtain comparable experimental conditions for the two methods, the same ball was used and the cylinders were made from the same bar, in the case of steel and brass, and were poured from the same melt, in the case of the lead cylinders. In addition to having cylinders of the same material throughout, caps of brass about $\frac{1}{4}$ in. thick and of lead about $\frac{1}{2}$ in. thick were made to screw onto the face of a steel cylinder so that impact would be made by the ball against the cap. The purpose of this arrangement was to determine the feasibility of having only one cylinder which, merely by the addition of caps, could be used to determine e for various combinations.

The following data and results are typical for a steel ball on steel cylinder:

(a) *Follow-through method.* $s_1=14.4$ cm, $s_1'=1.74$ cm, $s_2'=14.6$ cm, $m_1=544$ gm, $m_2=453$ gm; thus $e=(14.6-1.74)/14.4=0.89$. According to the momentum relation, 544×14.4 should equal $(544\times1.74)+(453\times14.6)$. From this inequality the accuracy is ±3 percent. Hence, $e=0.89$ ±3 percent.

(b) *Stop method.* $m_1=544$ gm, $m_2=625\pm20$ gm; thus $e=544/625=0.87\pm3$ percent, since the accuracy is taken as $\pm20/625=\pm3$ percent. These and other data are tabulated in Table I.

The results in Table I indicate that the stop method gives results consistent with the follow-through method and of about the same accuracy. It does not appear sufficient, however, to use caps of the desired material, at least of the thickness used in these experiments. The results with caps were invariably low, although some were within the limits of error, as Table I shows. An independent set of data was obtained by our technician, Mr. Eric A. Chandler, one year after the above set was obtained. The results are so nearly in agreement that they are not included. It is interesting to note, however, that he obtained 0.34 and 0.30 for the values of e by the follow-through and stop methods, respectively, for a lead ball and lead cylinder.

Using the simplest form of apparatus—a suspended ball and cylinder—one may verify the constancy of e merely by varying the arc through which the ball falls. The fractional loss of kinetic energy is also readily obtained, for it can be shown to be equal to $1-e$. Similar results are obtained by the method of rebound of a ball from a fixed heavy plate,[5] but the labor required to verify the law of the constancy of e is much greater.

If a graduated arc is used in connection with the stop method, it is then also possible to verify the law of the conservation of momentum, to compute, from experimental data, the loss of kinetic energy, thus providing a check of the value obtained from $1-e$, and to obtain a second experimental value for e from the relation $e=v_2'/v_1=s_2'/s_1$.

[5] Reference 2, Fig. 39.

NOTES ON APPARATUS AND DEMONSTRATIONS

The Theory of the Triode as a Three-Body Problem in Electrostatics

THE usual elementary textbook explanation of the action of the control electrode in a triode leads students to the belief that the grid in a triode must be placed between the filament and the plate in order to act as a "traffic" regulator of the electron stream in the tube.[1] Experiment shows that amplification can be secured when the grid and anode are on opposite sides of the filament as in the case of the internal grid tube of the type Pliotron FP110. Consider the triode with the filament cold as a system of three charged bodies. Let q_1, q_2 and q_3 denote the charges on the grid, filament and plate, respectively, and let V_1, V_2 and V_3 denote the corresponding potentials. By a fundamental principle of electrostatics the potentials of the three bodies may be written as follows:

$$V_1 = a_{11}q_1 + a_{12}q_2 + a_{13}q_3,$$
$$V_2 = a_{21}q_1 + a_{22}q_2 + a_{23}q_3,$$
$$V_3 = a_{31}q_1 + a_{32}q_2 + a_{33}q_3,$$

where the a's are constants depending upon the geometrical configuration. When these equations are solved for the q's we have a set of three equations of the form,

$$q_2 = c_{21}V_1 + c_{22}V_2 + c_{23}V_3,$$

where the c's depend upon the a's and are sometimes called mutual capacitances. As only the potential differences between the bodies, rather than the absolute potentials, interest us, let us suppose that the filament or body No. 2 is at zero potential and that the plate and grid are maintained at potentials e_p and e_g, respectively, relative to the filament, by means of batteries and connecting wires of negligible capacitances. We may now express the charge on the filament by

$$q_2 = c_{21}e_g + c_{23}e_p. \qquad (1)$$

This equation shows that the charge q_2 will change with the voltages e_g and e_p. Suppose that as e_g increases, e_p decreases so as to maintain the charge q_2 constant. Then, since

$$\Delta q_2 = 0 = c_{21}\Delta e_g - c_{23}\Delta e_p,$$

we have $$\Delta e_p/\Delta e_g = c_{21}/c_{23}.$$

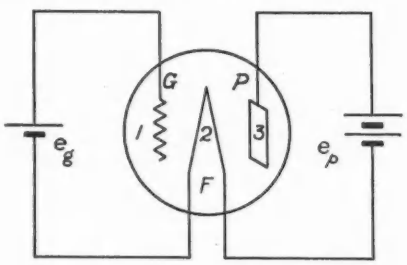

FIG. 1.

E. V. Appleton[2] designates this ratio by the symbol m and calls it the "magnification factor" of a triode with a cold cathode. We see that, as regards its effect on the charge q_2, 1 v on the grid is worth m v on the plate. Moreover, this ratio is independent of the capacitance of grid to plate. The grid and plate may therefore be located upon the same side or upon opposite sides of the cathode for the same value of m. Of course, we know that when the cathode is emitting electrons the mutual capacitance between electrodes is much greater if the space charge is present than if it is absent. For this reason m is not the voltage amplification factor of the ordinary triode. Nevertheless, a pure electrostatic analysis of a triode is helpful in understanding its actual behavior.

The quantity q_2 in Eq. (1) may be taken as a measure of the average electric field intensity near the cathode in the absence of space charge, for it is proportional to the number of lines of electric force ending on the cathode. Eq. (1) shows that whenever the potential of the grid is positive the field at the cathode is increased and whenever the grid is negative the field at the cathode is decreased, even when the grid is not situated in the direct path of the electron stream between the cathode and anode, as in Fig. 1. According to the usual elementary textbook explanation of the action of the control electrode, a positive charge on G should tend to lower the plate current while a negative charge on G should tend to increase the plate current. This is contrary to the experimental facts and also to what one expects on the basis of the simple electrostatic theory.

The writer has tested a triode consisting of a filament between two similar plates spaced at equal distances from the filament. It was found that a positive potential applied between the filament and either plate produced a rise in current to the other plate, and a negative potential between the filament and either plate caused the current to the other plate to fall.

ALEXANDER MARCUS

College of the City of New York,
New York, New York.

[1] E. D. McArthur, *Electronics and Electron Tubes* (Wiley, 1936), pp. 74–76.
[2] E. V. Appleton, *Thermionic Tubes* (Methuen, 1933), p. 38.

Demonstrations Useful for an Astronomy Survey Course

ALTHOUGH demonstrations of concepts and phenomena are most effective when made as much a part of the classroom routine as possible, in the case of science survey courses that meet in many sections a considerable expense is involved in stocking a number of classrooms with apparatus. At City College we have met this situation by equipping an exhibit room with demon-

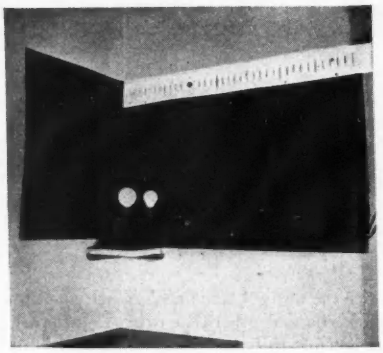

FIG. 3. Model of a binary star.

strations in astronomy, geology and physics. Every science survey class visits this room at least five times a semester. This note describes two astronomy exhibits in the room that are inexpensive and very easily grasped by the students.

Three-dimensional model of the Big Dipper.—A scale model of the Big Dipper with the seven principal stars shown in their true relative positions is available commercially. We believe we have materially improved this model merely by reproducing it with flashlight bulbs in place of the opaque white balls ordinarily employed (Fig. 1). In this way the model can be effectively demonstrated in a dark room and the "stars" look like stars. If a student sees a demonstration of a Copernican planetarium using white balls to represent the planets and, at the same time, sees the Big Dipper model with similar balls, he obtains a wrong impression of one of the essential differences between a star and a planet.

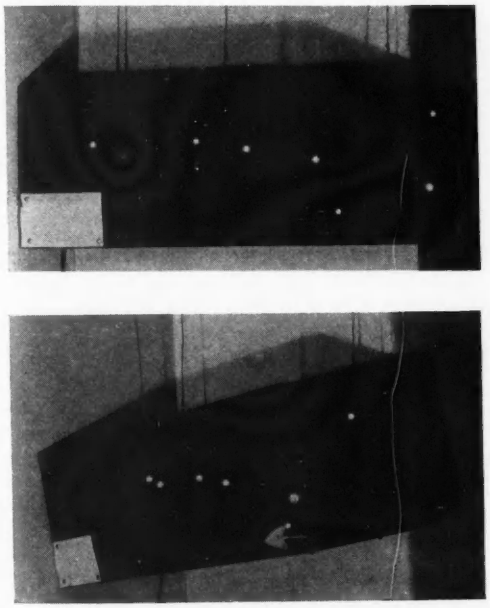

FIG. 1. Two views of the improved model of the Big Dipper.

Eclipsing binary star model.—Figures 2 and 3 show a refracting telescope and a model of a binary star. The binary system rotates at the rate of about 1 rev/min. The light from the binary is "seen" by a photronic cell which is placed in the telescope at the focal plane of the lens. The current generated in the cell passes through a galvanometer whose spot is thrown on the scale seen in Fig. 3 directly above the binary. By using electric light bulbs of different size and color in the binary the deflection of the galvanometer spot reproduces very nicely the light curve of an eclipsing binary. This demonstration has the advantage of showing the "star" and the corresponding light curve simultaneously.

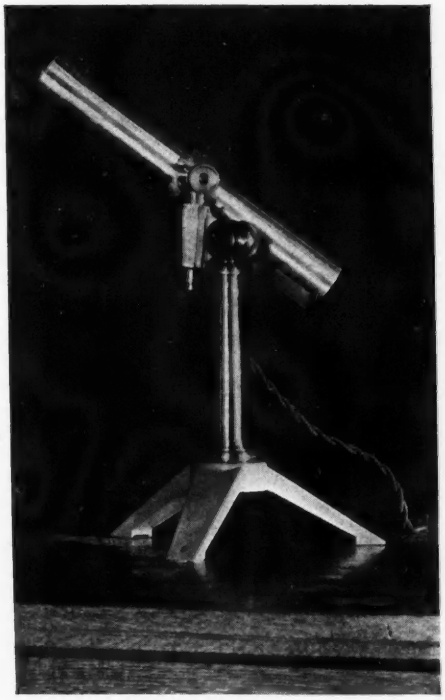

FIG. 2. Refracting telescope.

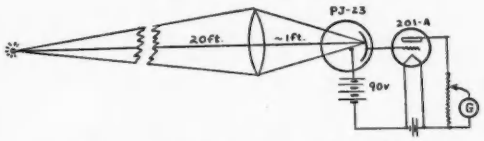

FIG. 4. Schematic diagram of proposed model.

Encouraged by the success of this model, we are planning an improved one which, in addition to a flashlight bulb

binary, will have a single flashlight bulb regulated to produce the light curve of a Cepheid variable. Fig. 4 shows a schematic arrangement designed to produce a 2-ft deflection on the galvanometer scale when a 1.5-v flashlight bulb is used at a distance of 20 ft from the lens. The photoelectric cell is a gas-filled type and the triode is used without plate voltage in order to reduce background current.

These models were constructed by Mr. Clark Wertenbaker of the Physics Department. I am grateful to Mr. Israel Antman of the same department for the photographs.

LEWIS BALAMUTH

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Attachment for Wall Galvanometer Telescope Holder

IN Fig. 1 is shown an attachment which has recently been applied to the telescope-and-scale holders used with the wall galvanometers in our laboratory. No explanation is needed, other than to say that the attachment makes it possible to focus the telescope and adjust the eyepiece without the telescope getting out of position, as it usually does when held only by the trunnion screws.

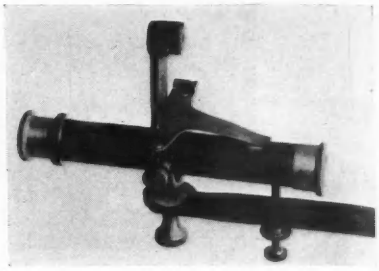

FIG. 1. Photograph of attachment.

WILLARD H. ELLER

University of Hawaii,
Honolulu, Territory of Hawaii.

Appointment Service

REPRESENTATIVES of departments or of institutions having vacancies are urged to write to the Editor, Columbia University, for additional information concerning the physicists whose announcements appear here or in previous issues. *The existence of a vacancy will not be divulged to anyone without the permission of the institution concerned.*

25. Ph.D. Yale. Age 33, married, 2 children. Industrial research experience; 3 yrs instructor in small college. Interested in teaching in coeducational or men's liberal arts college.

26. Ph.D., with long experience in an American college in China, wishes a college teaching position.

27. Ph.D., physics, Northwestern '35; A.B., engineering, Harvard. Age 42, married, 3 children. Experience: 1 yr, lt., artillery; 12 yrs business and sales; 5 yrs college teaching. Interested in undergraduate teaching, including astronomy.

28. B.S. in E.E., M.S., physics, Dr. Phil. Nat. from German univ. (Exchange fellow from U. S.) Age 33. 7 yrs teaching experience in advanced courses and physics for engineers.

29. Ph.D., Northwestern; M.S., Pittsburgh; A.B., Muskingum. Age 34, married, 1 child. Has had 13 yrs teaching experience in two universities. Interested in teaching and research.

30. Ph.D., Univ. of Chicago. Many years experience as head of department of physics in prominent college. Author of books on physics and history of science. Large work on history of physics in preparation. Interested in college or university teaching.

31. Ph.D. Columbia. Years of experience as head of departments of physics in colleges and universities. Author of new type of laboratory manual. Designer of many new types of simplified apparatus. Research in radio, acoustics and methods of teaching physics.

32. Ph.D., Age 33, married. Experience: 4 yrs secondary school; 4 yrs instructor state university; 3 mo industrial research; 4 yrs head of physics and mathematics departments in liberal arts college, where now employed. Author of laboratory manual. Three research grants. Desires position in larger college or university.

33. M.S., experimental physics, coupled with thorough background of courses in professional education. Has taught physics and mathematics for 3 yrs in large high school. Desires position as instructor in high school physics in a university or college experimental or training school.

Physics Contributions to *The Science Leaflet*

THE present editor of the physics section of *The Science Leaflet* has requested the support of the American Association of Physics Teachers in establishing a rotating group-editorship. This request has the endorsement of President K. T. Compton of Massachusetts Institute of Technology, *The Science Leaflet* being the organ of the Student Science Clubs of America, of which Dr. Compton is the president.

The *Leaflet* furnishes timely collateral readings in periodical form for students of secondary school sciences, the timeliness of its readings being secured by relating each of the weekly issues to those portions of the respective science subjects normally before the classes at the time of issue. Thus it correlates very closely with the curricular program and is the only periodical that arranges its material in this way.

The hope is that the Physics Department of a college or university will accept group responsibility for the weekly issues of one or, possibly, two years, this responsibility to be passed on to another similar group at the end of that time. The distribution of subject matter in accordance with the interests of the various members of the department will spread the load and insure the competence of the contributions. A special committee of the Association endorses this proposal and takes this way of bringing it to the attention of members. It is one way in which teachers at the college and university level can make a much-needed contribution to the effectiveness of secondary school instruction in physics.

Sample copies of *The Science Leaflet* are available. Correspondence concerning this proposal may be addressed to the chairman of the Association committee, Professor L. W. Taylor, Oberlin College, Oberlin, Ohio.

Summer Courses, Symposiums and Meetings

Columbia University

The graduate program for the summer session, July 5 to August 11, includes two courses by E. Teller of George Washington University, on *Quantum Mechanics* and *Introduction to Atomic Physics*. W. Heisenberg will give a series of lectures during one week of the session.

Cornell University

In addition to courses in *Advanced Laboratory Work*, *Molecular Physics* and *Electromagnetic Fields*, two advanced graduate courses on *Kinetic Theory of Gases* and *Statistical Mechanics* will be offered by E. H. Kennard.

Two different plans of study will be offered hereafter to the student who plans to study for the Master's degree in the summer sessions. The old plan, with major and minor subjects of limited scope and a thesis, is continued unchanged. Under the new plan the candidate chooses a "field of concentration" and a "field of distribution," instead of major and minor subjects; this will permit a wider distribution of the work offered for the degree. A substantial part of the work in the field of concentration will be devoted to studies requiring original investigation, organization of material and criticism by the student. Candidates may present either a formal thesis or an expository or critical essay. A minimum residence of five summer sessions (or one semester and three summer sessions), the completion of 30 semester hours of courses and other work, and the passing of a comprehensive final examination are required. The new plan is offered especially for the training of secondary school teachers now in service. This opportunity for wide distribution of work will be especially valuable for teachers of physical sciences.

Fordham University

Cosmic Rays, V. F. Hess; *Electricity and Magnetism*, W. A. Lynch; *Vector Analysis and Analytic Mechanics*, W. P. Hurley; *Theoretical Physics*. J. J. Lynch.

Massachusetts Institute of Technology

Practical Spectroscopy, June 12–July 22. A course of lectures for industrial and scientific workers who have had little previous spectroscopic experience, but desire training in spectroscopic methods. Any two weeks of the course may be taken. *Week 1*, design and operation of spectroscopic apparatus; *week 2*, photography; *week 3*, identification of spectrum lines, emission and absorption spectra, mechanism of light emission, excitation, and qualitative analysis; *week 4*, absorption spectrometry; *weeks* 5–6, quantitative analysis.

Applied Spectroscopy. A laboratory course, paralleling the lectures on practical spectroscopy. Six to 40 hours per week. Half-time registration for 6 weeks is recommended.

Spectroscopy Conference, July 17–19. Papers and discussions on photographic photometry, absorption spectrophotometry, analysis by the emission spectrum, industrial applications of spectroscopy, biological and chemical effects of spectral radiation, ultraviolet and infra-red spectroscopy, analysis of spectra and measurement of wave-lengths. Attendance limited to 200. No fee.

Spectroscopic Research, June 1–August 1. Qualified spectroscopists are invited to use the facilities of the laboratory. Students in other institutions who are doing thesis work involving spectroscopy may arrange to carry out the spectroscopic work in the laboratory during the summer.

Purdue University

W. Heisenberg of the University of Leipzig will be visiting professor during the summer session, July 1 to 22; he will lecture on problems in nuclear physics and cosmic rays. Special lectures for teachers' training will be given by I. Walerstein, H. M. James and other members of the staff. The cyclotron, neutron generator and accessory equipment will be available for experimental work in nuclear physics.

Stanford University

The American Association of Physics Teachers will meet at Stanford University on June 28, during the annual meeting of the Pacific Division of the American Association for the Advancement of Science. The program will include both invited and contributed papers.

V. Weisskopf and F. Bloch will give graduate courses during the summer session at Stanford University.

Syracuse University

"Science for the Citizen" is the general theme for a forum to be held under the joint auspices of the Science Division and School of Education on July 20. The invited speakers are: H. A. Sheldon, American Institute of the City of New York; Howard W. Blakeslee, Associated Press; Morris Meister, Bronx High School of Science, New York City; John Pierce, amateur telescope maker, Springfield, Vermont; Rose Lammel, Training School, Ohio State University; Duane Roller, Department of Physics, Hunter College; and Joseph Schwab, Department of Zoology, University of Chicago. Group discussions and the showing of new science films will also be features of the program.

University of Chicago

Two symposiums of interest to physicists will be held on June 23–30, as follows:

Liquids and Polyatomic Molecules, a joint symposium of the departments of physics and chemistry. The first part, on June 23–24, will be devoted to the liquid state (structure, viscosity, condensation, fusion, two-dimensional liquids, infra-red absorption and hydrogen bonding). The second part, on June 26–27, will include discussions of visible and ultraviolet spectra of complex molecules, the color of dyes, refractivity, optical activity, and liquid and molecular viewpoints in nuclear structure. The speakers will include K. F. Herzeld, B. E. Warren, J. G. Kirkwood, O. K. Rice, F. A. Ogg, Jr., J. E. Mayer, H. Eyring, W. D.

Harkins, W. H. Rodebush, L. Pauling, R. S. Mulliken, E. Teller, J. Franck and T. R. Hogness.

Cosmic Rays, June 27–30. The subjects to be discussed include intensity and absorption, geographic and geomagnetic effects, time variations, composition, energy distribution, showers and bursts, mesotrons and other heavy particles. The expected participants include P. Auger, W. Bothe, W. Heisenberg, P. M. S. Blackett, B. Rossi, J. Clay, G. Herzog, C. Anderson, V. F. Hess, T. H. Johnson, R. A. Millikan, W. F. G. Swann, M. S. Vallarta, A. H. Compton, W. P. Jesse, M. Schein and V. Wilson.

Graduate courses scheduled for the two summer terms, June 21–July 21 and July 24–August 25, include: *Physical Optics—Dispersion and Polarization*, H. G. Gale; *Nuclear Transformations*, A. J. Dempster; *Spectrometry*, G. S. Monk; *X-Rays Laboratory*, E. Dershem; *Line Spectra and Atomic Structure*, C. Eckart; *Electronic Structure of Molecules*, R. S. Mulliken; *Cosmic Rays and Allied Problems*, A. H. Compton; *Vector Analysis*, F. C. Hoyt; *Quantum Mechanics*, C. Eckart; *The Quantum Theory of Collision Processes*, F. C. Hoyt.

University of Iowa

The colloquium for college physicists to be held at the University of Iowa on June 15 to 16 will include the following addresses and other features:

Thursday, June 15

Demonstration Experiments. G. O. Gale, *Grinnell College;* H. W. Gould and D. L. Eaton, *Northern Illinois State Teachers College;* A. W. Hanson, *The Citadel;* J. Harty, *S. E. Missouri State Teachers College;* F. E. Hoecker, *University of Kansas City;* W. J. Hooper, *The Principia;* J. C. Jensen, *Nebraska Wesleyan University.*

Interesting Features of Recent Theoretical Physics. E. L. Hill, *University of Minnesota.*

The Use of Mathematics. Round table discussion, led by E. L. Hill, *University of Minnesota.*

Demonstration Experiments. A. F. Johnson, *Rockford College;* R. M. Morrow, *Iowa Wesleyan College;* R. H. Mortimore, *Graceland College;* H. K. Schilling, *Union College;* C. R. Smith, *Aurora College;* R. D. Spangler, *La Crosse State Teachers College;* V. F. Swaim, *Bradley Polytechnic Institute.*

Friday, June 16

The Teacher Looks at Current Research. T. H. Osgood, *University of Toledo.*

Merits of a General Physics Textbook. Panel discussion. J. W. Buchta, *University of Minnesota;* J. W. Woodrow, *Iowa State College;* R. R. Hancox, *Olivet College;* L. W. Taylor, *Oberlin College;* W. H. Kadesch, *Iowa State Teachers College;* C. N. Wall, *North Central College;* G. O. Gale, *Grinnell College;* W. Noll, *Berea College.*

Physics and Society. Round table discussion. W. S. Rogers, *Institute of World Affairs*, New York City; R. E. Park, *University of Chicago;* H. Feigl, F. M. Dawson and P. C. Packer, *University of Iowa.*

Saturday, June 17

X-Rays and Their Applications in Medicine. H. D. Kerr, *Department of Radiology, University of Iowa Hospital.*

X-Rays in Biological Research. T. Evans, *Department of Radiology, University of Iowa Hospital.*

The program will also include a visit to the x-ray laboratories of the University Hospital, the unveiling of a new mural, entitled "Man's Opportunities for a Better Civilization," in the library of the Department of Physics, motion pictures, and luncheon and dinner meetings. Notice of attendance and reservations in the University dormitories should be sent early to Professor G. W. Stewart.

University of Michigan

The seventeenth annual symposium in theoretical physics will be held from June 26 to August 18. Nuclear physics will be stressed, although other subjects will also be presented, particularly in the bi-weekly seminars and special lectures. The following series of lectures have been arranged.

Physics of High Energy Particles; Cosmic Rays. E. Fermi, *Columbia University.* Throughout the session.

Theory of Collission; Scattering of Fast Electrons and Cosmic-Ray Particles. E. J. Williams, *University of Wales.* July 12–August 12.

Band Spectra. G. Herzberg, *University of Saskatchewan.* Throughout the session.

The Interaction between Electromagnetic Radiation and the Nucleus. J. A. Wheeler, *Princeton University.* July 3–August 12.

Applications of Infra-Red Spectra to the Determination of Inter- and Intramolecular Forces. G. B. B. M. Sutherland, *Pemboke College, Cambridge.* July 24–August 5.

Advanced courses to be offered this summer include: *Electrical Measurements*, A. W. Smith; *Nuclear Physics*, H. R. Crane; *Spectroscopy*, R. A. Sawyer; *Sound*, F. A. Firestone; *Heat*, J. M. Cork; *Light*, W. W. Sleator; *Atomic Structure*, S. A. Goudsmit; *Electricity and Magnetism*, O. Laporte; *Theoretical Mechanics*, S. A. Goudsmit; *Quantum Theory and Atomic Structure*, O. Laporte; *Theory of Band Spectra*, G. Herzberg; *Conduction of Electricity through Gases*, O. S. Duffendack.

The department has engaged actively in industrial research over a period of fifteen years. These researches are maintained in the laboratory by the industries involved and are carried on by special investigators, although some member of the staff is associated with each project. As half a dozen or more such projects have been carried on simultaneously since this kind of work first began, a good deal of experience in the methods of industry and the applications of physics to its problems has been acquired at firsthand. Students desiring experience in industrial research as a prelude to a later professional career in industry will find summer courses and practical work offered in the general fields of sound and noise, photographic spectroscopy and infra-red spectroscopy. No one should come for practical work in any of these fields without first receiving permission.

University of Minnesota

First Session

Thermodynamics, J. W. Buchta; *Electrostatics and Direct Currents*, E. L. Hill; *Elementary Physical Investigation*, the

experimental or theoretical study of physical phenomena, Staff; *Modern Physics*, Lectures and readings on selected topics in current fields of research, J. H. Williams.

Second Session

Electrodynamics and Alternating Current Circuits, J. Bardeen; *Elementary Physical Investigation* (continued), Staff; *Advanced Heat*, L. F. Miller; *Electrical Measurements*, L. H. Rumbaugh.

University of Pennsylvania

Advanced Laboratory Work. Experiments in electricity, physical optics and modern physics, selected to meet the needs of individual students. Three hours daily. R. W. Duncan and L. N. Ridenour.

Classical Physical Methods. Applications of mathematics to the solution of problems in classical physics. Topics will be selected as far as possible to meet the needs of individual students. R. D. Summers.

Modern Physical Theories. Modern quantum theory, from its experimental beginnings to the development of Dirac's relativistically invariant formulation, with emphasis on the logical aspects of the various developments rather than on their mathematical minutiae. L. N. Ridenour.

The graduate courses will be planned mainly to meet the needs of candidates for the Master's degree and also of graduate students in the School of Education.

University of Pittsburgh

Continuing the policy of last year, the department has arranged a special session on "Physics of Metals," from July 6 to August 11, in which physicists and metallurgists will cooperate in lectures and discussions on recent progress in the physics of metals and possible applications in the field of metallurgy. In addition to weekly colloquiums on topics of especial interest, the following formal courses will be offered:

Introductory Electronic Structure of Metals. J. C. Slater.
Elementary Atomic Physics. M. F. Manning.
Modern Theory of Solids. W. Shockley.
Electric and Magnetic Properties of Metals. F. Seitz.
Introductory Statistical Mechanics. E. U. Condon.
Theory of Atomic Vibration. J. C. Slater.

A regular program of summer courses will also be available from July 6 to August 21.

Pacific Science Congress

The sixth Pacific Science Congress will be held at Berkeley, Stanford and San Francisco during July 24 to August 12, 1939, under the auspices of the National Research Council. Previous congresses in this series have been held at three-year intervals in various countries of the Pacific region. In accordance with the plans of the previous congresses, the present congress will "emphasize the discussion of comprehensive scientific topics of general interest to the people of the Pacific basin," and the theme will be "the present stage of knowledge of Pacific scientific problems and methods by which that knowledge may be most profitably enlarged." As the Congress is designed for discussion and interchange of ideas rather than for precise formulation of attempted solution of problems, the program will consist of a series of symposiums rather than of independent papers. Among the subjects on the program of particular interest to physicists are the geophysics and meteorology of the Pacific basin.

The official representatives of the American Association of Physics Teachers at the Congress will be Professor A. A. Knowlton, of Reed College, and Professor Paul Kirkpatrick, of Stanford University. Additional information concerning the Congress may be obtained by addressing Dr. Roy E. Clausen, Room 205, Hilgard Hall, University of California, Berkeley.

Meetings of the Oregon Chapter

The Oregon Chapter of the American Association of Physics Teachers met on February 18 at Oregon State College. The program was as follows:

Photoconductivity. J. J. Brady, *Oregon State College.*

The Annual Meeting of the Association at Washington. A. A. Knowlton, *Reed College.*

Laboratory Apparatus for High Schools. W. L. Woodson, *Oregon State College.*

The Basis of Modern Television. F. A. Everest, *Oregon State College.*

Tricks of the Trade. M. O'Day, *Reed College.*

Teaching Kinks. W. Haynes, *Oregon Institute of Technology.*

Discussion of the Report of the A. A. P. T. Committee on the Teaching of Geometrical Optics. W. Weniger, *Oregon State College.*

On April 29 the chapter met at the Oregon Institute of Technology for the following program:

Chinese Weights and Measures. Lui Chung Kwai, *Oregon State College.*

The MKS System. W. R. Varner, *Oregon State College.*

Shall the MKS System Be Taught Next Year? W. Haynes, *Oregon Institute of Technology.*

Vibrations of the Atoms in Crystal Lattices. P. C. Fine, *University of Oregon.*

Color Photography. D. L. Hunter, *University of Oregon.*

Teaching Devices Designed to Inspire Interest in Physics. H. E. Hewitt, *Linfield College.*

Professor A. E. Caswell, University of Oregon, is president of the chapter. Professor W. R. Varner, Oregon State College, is secretary.

RECENT PUBLICATIONS AND TEACHING AIDS

First-Year Textbooks

Introductory College Physics. Oswald H. Blackwood, Professor of Physics, University of Pittsburgh, 501 p., 423 fig., 37 tables, 15×23 cm. *Wiley*, $3.50. The course in general physics provided by this new textbook is planned to appeal to the needs and interests not only of science majors but of the large number of general students who would profit greatly by an acquaintance with physics and the role it plays in a modern technologic age. The author believes that the interests of such students must be stimulated by providing illustrative material that is very familiar and of vital concern to them—for example, the exceedingly diverse and important experiences and applications associated with automobiles and with the world of sports—and by presenting the science as humanistic and ever-growing through the use of historical material and contemporary physical achievements. Although the book is traditional in its general arrangement, the author has tried to introduce the subject matter in such a way as to guard the student from discouragement, particularly in the early weeks of the course; his treatment of simple harmonic motion, for example, is deferred until the second semester, when it is needed in treating vibrations. Each chapter contains a summary, and lists of review questions and problems. Numerous illustrative examples are worked out in detail. The diagrams and their explanatory legends are exceptionally useful and attractive.

Intermediate and Advanced Textbooks and References

The Sun. Its Phenomena and Physical Features. Giorgio Abetti, Royal Observatory of Arcetri. Tr. by A. Zimmermann and F. Borghouts. 360 p., 157 fig., 25 tables, 15×23 cm. *Van Nostrand*, $5. A survey of the physics of the outer layers of the sun, the methods employed in solar problems, and the probable character of future studies is provided in this English translation and revision of an Italian book first published in 1936. Any reader who is conversant with the elements of physics will find the book clear and understandable. For the astrophysicist it provides a brief summary of many recent researches and a very complete account of sun spots and markings, and their measurement.

Procedures in Experimental Physics. John Strong, Associate Professor of Physics in Astrophysics, California Institute of Technology. 652 p., 416 fig., 63 tables, 15×23 cm. *Prentice-Hall*, $5. Every experimental physicist and student should have access to this valuable and much-needed book. It contains a wealth of information on all kinds of experimental technics—glass blowing, optical shop work, high vacuum, evaporated and sputtered surfaces, use of fused silica, electrometers and electroscopes, Geiger counters, vacuum thermopiles, light sources and filters, optical instruments, photoelectric cells and amplifiers, photography, high temperatures, materials and substances used in physical research, molding and casting, and instrument design and construction. H. Victor Neher, Albert E. Whitford (astronomy) and C. Hawley Cartwright collaborated with the author in the compilation of the book. D. O. Hendrix and R. M. Langer also contributed material. The many, exceedingly informative diagrams were prepared by Roger Hayward, an architect.

Physical Meteorology. John G. Albright, Assistant Professor of Physics, Case School of Applied Science. 419 p., 246 fig., 22 tables, 15×23 cm. *Prentice-Hall*, $5.35. Because modern meteorology is becoming so important in practice and, especially, because it is making increasing use of fundamental physical principles and methods, it is highly desirable that more physics departments consider the possibility of offering courses in the field. Textbooks that emphasize modern methods and the underlying physics have been scarce, however, and hence the present book represents a type that is timely and has been badly needed. The book is suitable for an intermediate course for students who have had general college physics. Simple calculus is used in a few of the derivations, but the treatment is so arranged that derivations of formulas may be omitted if the student lacks adequate mathematical preparation, or if a briefer course is desired. The main topics treated are: the composition, height and pressure of the atmosphere; barometric and temperature measurements; insolation; water vapor in the atmosphere; thermodynamics of the atmosphere; dynamics of air movements; condensation and precipitation; cyclonic storms; atmospheric electricity, acoustics and optics. There is also a chapter on heat and radiation theory but this may be omitted if the student's preparation is adequate. Lists of questions and problems accompany the chapters.

Kinetic Theory of Gases. Earle H. Kennard, Professor of Physics, Cornell University. 496 p., 94 fig., 23 tables, 15×23 cm. *McGraw-Hill*, $5. Designed to serve as a text for upper division students and as a reference for experimentalists, this book provides a treatment of the kinetic theory of gases from the modern point of view. The more fundamental aspects of the subject are treated in considerable detail. The first eight chapters deal with: the elements of the kinetic theory of gases; the distribution law for molecular velocities; the general motion and spatial distribution of the molecules; viscosity, thermal conduction and diffusion; equations of state; energy, entropy and specific heats; fluctuations; and properties of gases at

low temperatures. The next two chapters are devoted, respectively, to a concise introduction to general statistical mechanics and an account of the wave-mechanical theory of gases, including the Fermi-Dirac case. The last chapter deals briefly with the dielectric constant, magnetic susceptibility and motion of electricity in gases. Not many problems or exercises are provided, but proofs of a number of the theorems in the text are left to the student. As the author points out, formerly it was hoped that the theory of gases could ultimately be treated as a part of a general kinetic theory of matter; but the theory of condensed phases, insofar as it exists at all today, involves so elaborate a use of wave mechanics that it is best treated as a subject by itself.

Principles of Electricity and Magnetism. GAYLORD P. HARNWELL, Professor of Physics, University of Pennsylvania. 632 p., 381 fig., 13 tables, 15×23 cm. *McGraw-Hill*, $5. Electricity and magnetism is developed from the point of view of the experimental physicist rather than the engineer or the mathematician in this new textbook designed for students who have had thorough courses in general physics and in mathematics through integral calculus and elementary differential equations. Vector notation is employed but the necessary general vector theory, and also a summary of common types of differential equations, is given in a mathematical appendix. The treatment begins with electrostatics and proceeds to the non-magnetic phenomena associated with currents. Nonohmic circuit elements and conduction in gases are discussed at unusual length. Magnetism is approached from the point of view of electromagnetic phenomena, the pole concept being afterwards introduced mainly because it makes possible the development of a formal analogy between electrostatics and magnetostatics that is a useful aid in calculation. The treatment of alternating-current circuit theory is modern, the emphasis being on aspects of importance in present-day research and also in communication. The final chapter deals with radiation, particularly radiation of the frequency range generated by electric circuits. Throughout the text consistent use is made of the practical system of units built on the joule, coulomb, ohm, meter, kilogram and second as basic, although the other possible systems are also discussed and used explicitly to some extent.

HISTORIES AND ORIGINAL MEMOIRS

A History of Science, Technology and Philosophy in the Eighteenth Century. A. WOLF, Head of the Department of History and Philosophy of Science, University of London. 814 p., 345 figs. and photographs, 15×24 cm. *Macmillan*, $8. Similar in general character to the same author's well-known work on the sixteenth and seventeenth centuries [Am. Phys. Teacher **4**, 148 (1936)], the present volume dealing with the eighteenth century places emphasis on achievements and problems, not on personalities; and it covers all the sciences and their applications, and has chapters on the social fields and philosophy. The sciences—including meteorology, geography and medicine—are discussed separately and in the order of diminishing abstraction. Next comes a very comprehensive treatment of technology in all its main developments—agriculture, textiles, building, transportation and communication, power sources and machinery, mining, metallurgy, industrial chemistry, and optics. The closing chapters deal with those aspects of psychology, demography, economics and philosophy that are of most importance to the student of science. About one-fifth of the book is devoted to the history of pure physics in the eighteenth century, and this does not include the large amount of material on physical applications to be found in the sections on technology and the other sciences. In the Preface the author remarks, "At a time when large sections of the civilized world are reverting to barbarism, it is especially stimulating to study the age in which Europe was struggling, and successfully struggling, towards a state of enlightenment. What mankind has achieved once it will assuredly achieve again, and achieve, it is to be hoped, with a fuller realization of the need of eternal vigilance as the price of freedom, so essential to human progress."

The Physical Treatises of Pascal. Tr. by I. H. B. and A. G. H. SPIERS, with an introduction and notes by FREDERICK BARRY. 209 p., 35 fig. and plates, 8 tables, 14×23 cm. *Columbia Univ. Press*, $3.25. PASCAL'S *Traitez de l'equilibre des liquers et de la pesanteur de la masse de l'air*, which appear in translation in the present volume, have not heretofore been generally available. The early editions are somewhat scarce, and the two existing editions of PASCAL'S works—14 and 3 volumes, respectively—are usually accessible only in large libraries. Important excerpts are to be found in MAGIE'S *A Source Book of Physics* [Am. Phys. Teacher **4**, 47 (1936)] but they are necessarily somewhat brief, representing roughly a tenth of the complete work. The two treatises, which were assembled and published by PERIER in 1663, a year after PASCAL'S death, contain a complete summary of the parts of PASCAL'S work that are of most interest to physicists; namely, the first conclusive proof of the pressure of the atmosphere and the statement of the laws of fluid pressure, the latter giving a mechanical correlation of the diverse phenomena of fluid equilibrium and serving to unify hydrostatics and aerostatics into a deductive, logically coherent science. This scientific classic, PROFESSOR BARRY points out in the Introduction, "is one of the few that provides the student of the history of science with a succinct yet entertainingly vivid picture of the spontaneous enthusiasm and experimental ingenuity that characterized the scientific work of the seventeenth century; and because it logically develops a single thesis, it exhibits, as no commentary could, the powerful synthetic thought of this master of scientific method." The translation of the two treatises occupies less than half of the present volume. In addition to numerous editorial notes, there are some 55 pages of excerpts from PASCAL'S letters and other works, and a 36-page appendix containing translations of part of STEVIN'S "Fourth Book of Statics," all of his "Fifth Book," "GALILEO'S Remarks on Nature's Abhorrence of a Vacuum" (quoted from CREW and DE SALVIO'S translation of *Two New Sciences*) and TORRICELLI'S letters on the pressure of the atmosphere.

Popular Books

These Amazing Electrons. Raymond F. Yates. 333 p., 109 fig. and plates, 13×21 cm. *Macmillan*, $3.75. This well-illustrated popular treatment first traces the development of atomic physics and then carries the reader on to the everyday world, describing the applications of electronic devices to medicine, surgery, music, television and industrial uses.

Atomic Artillery. John K. Robertson, Professor of Physics, Queens University, Kingston, Canada. 191 p., 26 fig., 3 tables, 13×20 cm. *Van Nostrand*, $2.25. Published in 1937, this nonmathematical treatment deals pleasingly and briefly with the story of electrons, protons, positrons, photons, neutrons and cosmic rays, and with radioactivity and the recent achievements of modern alchemy. Both the intelligent layman and the beginner in science should find the book interesting.

Atoms, Men and Stars. Rogers D. Rusk, Associate Professor of Physics, Mount Holyoke College. 326 p., 20 fig., 14×22 cm. *Knopf*, $3. The progress of physics and also of its applications in the form of inventions is dealt with in this skilfully written book for the lay reader. A strong historic and humanistic note prevails in the treatment, with resulting emphasis on the idea that science is essentially a way of living. Although the results of a few of the author's rather frequent excursions into extra-scientific domains may appeal to some readers as being somewhat fanciful and inaccurate, the book as a whole represents a type of popular treatment that should be of genuine use and interest to many lay readers.

The Book of Time. Gerald Lynton Kaufman. 303 p., 1 plate, 14×22 cm. *Messner*, $3. The author is a professional architect who studies time as an avocation. His book is clearly written and should provide stimulating reading for the layman who is intellectually curious. The 39 varieties of the time concept encountered in the sciences, philosophy and everyday life are, according to the author: Newtonian absolute, absolute, abstract and concrete, adequate, clairvoyant, clock, conceptional, continuous, directional, duration, enjoyed, fourth-dimensional, Galilean, homogeneous and heterogeneous, hypnotic, idealistic, indifference, indivisible, instant, intuitive, mean, mental, metaphysical, natural, noumenal, objective, perceptual, physical, physiological, psychological, relative, relational, reversible, real, sidereal, solar, space-, standard and universal time.

Miscellaneous Books

Fundamental Electronics and Vacuum Tubes. Arthur Lemuel Albert, Professor of Communication Engineering, Oregon State College. 431 p., 284 fig., 9 tables, 15×23 cm. *Macmillan*, $4.50. This text is designed primarily for students of electrical engineering. The first three chapters present basic electronic phenomena and theories; the next four, a discussion of all types of high vacuum and gas tubes; the final eight, applications of these electronic devices to communication and power engineering. Emphasis is placed on fundamental principles, the development of most mathematical equations being omitted. Numerous well-chosen references to original papers and texts are given. The standards of the American Institute of Electrical Engineers and of the Institute of Radio Engineers are followed throughout the book.

A Manual of Style. Ed. 10. 493 p., 14×21 cm. *Univ. of Chicago Press*, $3. Typographic and literary rules are brought up to date in the present edition, the tenth since the first publication of this manual in 1906. Although intended primarily for use in connection with University of Chicago publications, the manual is regarded by many authors and editors as a valuable and authoritative aid in the preparation of manuscripts for books and articles.

Charts and Posters

The Tree of Knowledge. 69×95 cm. *Museum of Science and Industry* (Jackson Park, Chicago, Ill.), 25 cts. A reproduction in four colors of a large mural painting in which the basic sciences are represented as the roots of a large tree, and the applied sciences as its branches.

Display Chart on Aluminum. 43×70 cm, heavy cardboard. *Aluminum Co. of America* (2106 Gulf Bldg., Pittsburgh, Pa.), gratis to colleges and secondary schools. One side of the chart gives the history, mining and manufacture of the raw materials used in the production of aluminum, and has mounted on it actual samples of the various raw materials. On the reverse side, a diagram traces each step in the production of the metal from the mining of bauxite through the fabrication of the primary aluminum products. Requests for the chart should be made on the letterhead of the institution.

Motion Picture Films

We Drivers. 16 or 35 mm, sound film or silent, 12 min. *Y. M. C. A. Motion Picture Bureau* (347 Madison Ave., New York, or 19 S. La Salle St., Chicago), loaned gratis. This film won a national award for the outstanding contribution to safety in 1936.

Where Mileage Begins. 16 or 35 mm, sound film or silent, 25 min. *Y. M. C. A. Motion Picture Bureau*, loaned gratis. Animated diagrams showing the principles and operation of a gasoline engine; assembly of an automobile engine. Sponsored by General Motors Corporation.

Voices in Paper. 16 or 35 mm, sound film, 12 min. *Y. M. C. A. Motion Picture Bureau*, loaned gratis. A Western Electric Co. film showing the manufacture of lead-covered, telephone cables and methods of making paper pulp insulation direct on the wires.

Copper Refining. 16 or 35 mm, silent, 15 min. *U. S. Bureau of Mines* (4800 Forbes St., Pittsburgh), loaned gratis. Produced by the Phelps Dodge Corporation, this film shows the conversion of anode slabs into chemically pure copper. Other films in this new series are *Copper Mining in Arizona* (45 min), *Copper Leaching and Concentration* (15 min), and *Copper Smelting* (15 min).

DIGEST OF PERIODICAL LITERATURE

Apparatus and Demonstrations

The plane mirror experiment. G. W. Warner; *Sch. Sci. and Math.* **39**, 277–78, Mar., 1939. A chrome-plated steel mirror, glued to a supporting block of wood, is no more expensive than a silvered glass mirror, will not break if dropped, does not scratch or tarnish easily, and does not involve refraction effects, which are appreciable in a glass mirror even when it is thin. The steel mirrors may be obtained from apparatus dealers or, in any size desired, from the Apollo Metal Works, 6650 Oak Park Ave., Chicago. Several other suggestions for plane mirror experiments are given in the original article.—D. R.

Three inexpensive demonstration and laboratory aids. W. S. Drury; *Sch. Sci. and Math.* **39**, 168–69, Feb., 1939. (1) Thermostatic "Bimetal," a commercial product of brass and Invar welded or brazed together, is much more sensitive than the familiar riveted strips of brass and steel for demonstrating differential expansion. A thin strip held over a match flame will curl back on itself, and even thicker pieces are visibly deformed. It is available in sheets or strips, or shaped into spirals and other forms, in thicknesses from 0.005 to 0.1 in., and is made by the W. M. Chace Co., 1600 Beard Ave., Detroit, Mich. (2) "Gift Wrap" Scotch cellulose tape, available in $\frac{1}{4}$- and $\frac{1}{2}$-in. widths at stationary and ten-cent stores, is useful for marking glassware and apparatus. It sticks without wetting, pulls off clean, and has brilliant shiny colors that are visible at a great distance. (3) Glass imitation ice cubes, available at Woolworth stores, are useful in the study of liquid pressure to represent cubes of water piled one on top of the other, and also serve as small density samples and for showing strain patterns with polarized light.—D. R.

A simple method of crystal model construction. K. M. Seymour; *J. Chem. Ed.* **15**, 192–94, Apr., 1938. Although models of certain common crystals can be purchased, the variety available is very limited and the cost is large; furthermore, it is advantageous to have students construct some of these models themselves. The author investigated the possibilities of using modeling clays, plaster of Paris, sealing wax, wooden balls and marbles to represent the atoms or ions, but finally chose lacquered, sponge rubber balls which can be obtained in a variety of sizes and bright colors from ten-cent stores or toy wholesalers. The best, inexpensive material for connecting rods is $\frac{1}{4}$-in. oak doweling. A better material is $\frac{3}{32}$-in. brass rod, but it is more expensive and corrodes rapidly in the laboratory atmosphere unless carefully lacquered. Monel metal rod, although still more expensive, is suggested as the best material for permanent models. In using the doweling, an ordinary brass cork borer makes the most suitable hole. Care must be taken to locate the holes properly, or the model will be distorted.

In constructing a model the student should proceed as follows: (1) find from the literature the most reliable data for the dimensions of the unit cell of the crystal and of its constituents; (2) from the balls available, choose those having a radius ratio nearest the accepted value; and (3) compute the proper dimensions of the unit cell by proportion from the radius of the balls used and the radius of the atom or ion represented; if the radius ratio of the balls is appreciably different from the accepted ratio, the dimensions of the unit cell should be taken as the mean of the respective values computed from the two balls. In the author's models, the polarization of the ions was neglected. Although it is possible to deform the soft balls to approximate the effects of polarization, this would require some more rigid means of holding the balls in position.—D. R.

Tough soap films and bubbles. G. A. Cook; *J. Chem. Ed.* **15**, 161–66, Apr., 1938. The literature was searched and various experiments were made to find the best simple directions for making soap solutions that could be prepared quickly from readily available materials and that would yield bubbles lasting from 1 to 5 min in the open air without special preparation. This lifetime is ample for all ordinary lecture experiments. For open-air work, triethanolamine oleate solutions were found to be greatly superior to Castile soap solutions, although the latter gave bubbles that are satisfactory for the average experiment. Directions for the best solutions are as follows:

Castile soap. Place 30 gm of the powdered soap in a 1-l glass-stoppered bottle, fill the bottle with distilled water, shake occasionally until solution is completed, and then allow to stand for 24 hr or more. The solution does not become entirely clear, but sufficiently so for use. Siphon off the clear portion, thoroughly mix it with $\frac{3}{10}$ of its volume of glycerin, and allow it to age for at least 24 hr. Store in a dark place in a well-stoppered bottle. When ready to use the solution, pour out about 25 ml and stir with only about 25 to 100 mg of tannin.

Triethanolamine oleate. Thoroughly stir any convenient weight of triethanolamine with a little less than twice its weight of oleic acid in a flask. Keep the flask stoppered for 24 hr. Mix 30 gm of the resulting soap with about 1-l of distilled water, shake occasionally as it slowly dissolves, and allow to settle for 24 hr. Siphon off the lower light gray layer, mix it well with $\frac{3}{10}$ of its volume of glycerin and let it age for 24 hr. Store in the dark in a well-stoppered bottle.

Of various kinds of pipes tried, an ordinary straight-stemmed tobacco pipe, with a bowl made of hard smooth composition material, was found to be as satisfactory as

any. The interior of the bowl should be thoroughly wet with the solution. The slow steady stream of gas used to blow the bubble should not be turned on until after the pipe is dipped into the solution. If the gas contains grease, etc., it should first be passed through a glass tube containing cotton moistened with glycerin.—D. R.

Standards of Musical Pitch

International standard of musical pitch. G. W. C. Kaye; *Nature* **142**, 820–21, Nov. 5, 1938. It has long been customary to express musical pitch in terms of the frequency of the note *A* in the treble clef. From the fourteenth to the seventeenth centuries *A* wandered over a range of nearly 200 cycle/sec, from 374 to 567, but by the nineteenth century the spread was only from 424 to 494. In 1826 the London Philharmonic pitch was based on a value of 433 for *A* but 19 years later this was changed to 455. A Stuttgart conference of physicists in 1834 adopted 440. A French conference in 1859 established the "Diapason Normal," based on 435, the associated instrument temperature being 59°F; this pitch, which was legalized in France, was adopted by the Boston Symphony Orchestra in 1883 and endorsed by an international conference at Vienna in 1885. In 1896 the Philharmonic Society adopted 439 at 68°F, while in 1899 an international discussion by the pianoforte trade resulted in the adoption of the same value. In 1927 the pitch of British army bands was lowered from 455 to 439 at 68°F. In the United States, after many vagaries, a figure of 440 for *A* is now universal, having been adopted by the American Federation of Musicians in 1918, the Music Industries Chamber of Commerce in 1925, and the American Standards Association in 1936. This figure is in good agreement with the usual British one, as the temperature in American concert halls is customarily about 70°F.

The problem of the international standardization of musical pitch has recently assumed a new importance because of the exchange of concert programs by broadcasting organizations in various countries. A recent British conference, attended by representatives of 30 musical and other organizations, agreed unanimously that the British Standards Institution should attempt to secure an international standard of pitch, and a small committee has begun its work. It was found that the British Broadcasting Company had provisionally adopted 439 for *A* and that many musical broadcasts from different countries in Europe were based on a pitch which averaged about 443. It would seem that an international figure for *A* should be at or near 440.

A secondary duty of an international conference would be to deal specifically with the temperature question. Many musical instruments exhibit appreciable temperature variations of pitch. In the wind organ, which presents the major problem, the pitch rises about 1 part in 1000 for 1°F temperature rise. In wind and reed instruments, which are influenced by warmth of breath, fingering, etc., the temperature effects are on the average about half as large. Stringed instruments present no difficulty, the pitch of a piano falling by only 1 part in 18,000 for 1°F temperature rise. A great difficulty in most concert halls is the steady rise in temperature as the concert progresses; it often causes a rise of 5 cycle/sec or more in the pitch of an orchestra.

For an orchestral standard of pitch the oboe, though often used, is demonstrably unsatisfactory. The piano is better, a steel tuning fork better still, and an elinvar fork with a temperature coefficient of less than 40 parts in 10^6 best of all.

Two features likely to simplify the temperature question in the future are the increasing vogue of air conditioning and the rapid development of electroacoustic instruments, such as the electric organ, which have no temperature coefficient. Incidentally, the values of *A* in two well-known makes of electric organ are 439 and 440, respectively.

Temperature variations are especially troublesome out-of-doors, but at present international agreement can be secured only for reasonable concert hall conditions. Until conditions are such that instrument pitches are free from temperature change, the working temperature must be specified, and 68°F seems likely to be acceptable to a majority of nations.

An international conference on musical pitch may be convened in 1939. Those interested should communicate with the Director, British Standards Institute, 28 Victoria Street, London.—H. N. O.

Check List of Periodical Literature

The cyclotron and its applications. J. D. Cockcroft; *J. Sci. Inst.* **16**, 37–44, Feb., 1939. A brief survey of the principle, construction, adjustment, output and applications of the cyclotron.

Let us start all over again. R. F. Tiffany; *J. Franklin Inst.* **227**, 111–18, Jan., 1939. Describes a more rational and orderly method for coordinating and using the results of research.

Albert Abraham Michelson. R. A. Millikan; *Sci. Mo.* **48**, 16–27, Jan. 1939. Gives many intimate details concerning Michelson's life, personality and scientific work.

Research in industry. F. B. Jewett; *Sci. Mo.* **48**, 195–202, Mar., 1939. A general discussion of the role, management and future possibilities of industrial research.

The operational calculus. III. L. A. Pipes; *J. App. Phys.* **10**, 301–12, May, 1939. The last of a series of three articles on the use of the operational method in attacking various typical problems.

Report on the examination in physics—elementary of the College Entrance Examination Board, June 22, 1938. A. Longacre and R. F. Bartlett; *Sch. Sci. and Math.* **39**, 369–74, Apr., 1939. A detailed, critical analysis of the examination by two members of the science staff of Phillips Exeter Academy.

A résumé of electron diffraction. G. L. Clark and E. Walthuis; *J. Chem. Ed.* **15**, 64–75, Feb., 1938. A complete review of the essential developments, with emphasis on applications to chemical analysis.

Some experiences in teaching general chemistry to arts students or its cultural value. C. F. Adams; *J. Chem. Ed.* **15**, 415–19, Sept., 1938. A useful, illuminating and detailed discussion of the author's experiences with chemistry and physics-chemistry survey courses at Antioch College.

The production and properties of neutrons. N. Feather; *Sci. Progress* **33**, 240–56, Oct., 1938. A survey.